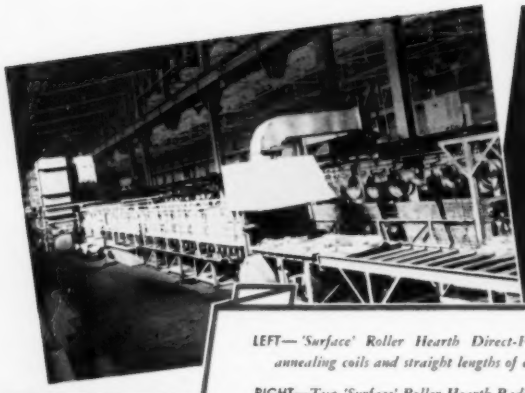
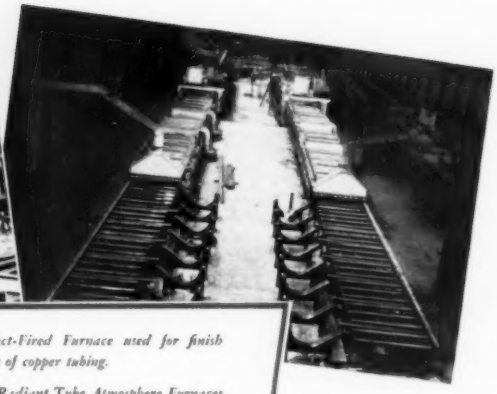
METAL PROGRESS

JULY 1951

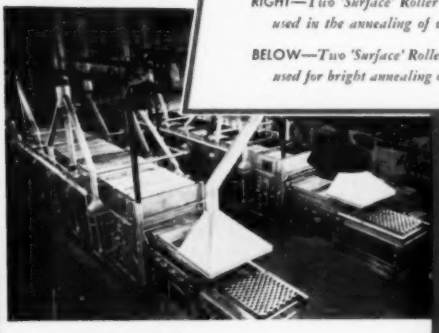




LEFT—*'Surface' Roller Hearth Direct-Fired Furnace used for finish annealing coils and straight lengths of copper tubing.*

RIGHT—*Two 'Surface' Roller Hearth Radiant Tube Atmosphere Furnaces used in the annealing of welded aircraft tubing.*

BELOW—*Two 'Surface' Roller Hearth Radiant Tube Atmosphere Furnaces used for bright annealing of steel cartridge cases.*



'SURFACE' Roller Hearth FURNACES

Radiant Tube and Direct-Fired

Send for Bulletin SC-132 today! Describes both Radiant Tube and Direct-Fired Roller Hearth furnaces as applied to numerous heat treatment operations.

For annealing, normalizing, clean hardening and many other heat treating processes on tubing, coils, disks and sheets. Ideal for small and large parts, such as shell cases, which are readily moved in baskets or trays.

ENGINEERING FEATURES

HEATING—direct-fired or radiant tube, as required, to provide uniform temperature and uniform heat distribution throughout the furnace.

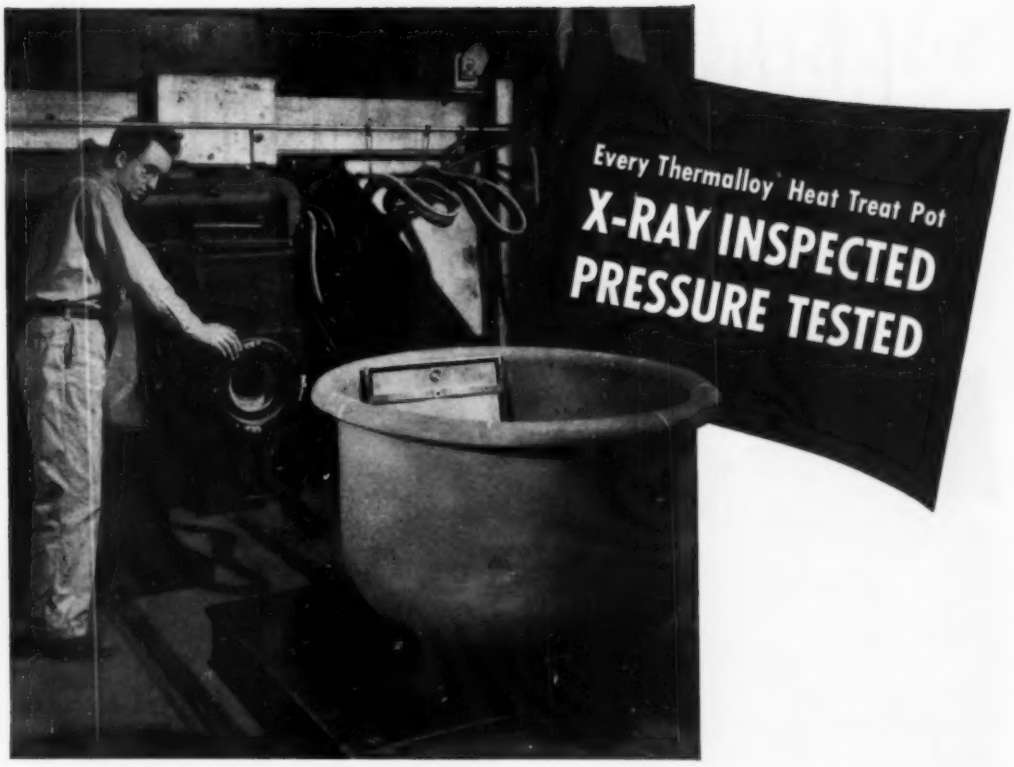
ATMOSPHERE CONTROL—Gas-tight construction and radiant tube heating permit precise control of furnace atmosphere.

EXCLUSIVE MECHANICAL CONSTRUCTION—Rollers designed with external bearings and drives provide uniform speeds and hearth alignment with minimum maintenance.

The direct result of these and other 'Surface' features is *near-standardization by steel and non-ferrous metal processors on Surface Combustion Roller Hearth Furnaces.*

'Surface' INDUSTRIAL FURNACES

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO



Another reason why you get
More Operating Hours per Dollar

To insure the soundness necessary for low-cost service, every Thermalloy Heat Treat Pot is subjected to thorough internal and external inspection. Two X-ray machines, operated by trained radiographers, reveal any hidden flaws or weaknesses which might shorten service life. Pots are also pressure-tested at 60 pounds per square inch. This eliminates the possibility of porosity that does not show up on X-rays.

This careful inspection, plus Thermalloy's outstanding heat-resistant properties, are your guarantee of top quality. Why not make Thermalloy your standard in buying heat treat pots?

HERE'S PROOF OF QUALITY!

- Life of Electro-Alloys neutral salt pot proved to be eight times that of competitive type pot formerly used. User saved over $100 on initial cost alone during life of one pot—plus replacement labor costs of seven pot changes.

- With a competitive alloy, customer was receiving 1,500 to 3,500 hours service. On switching to Thermalloy pots, service life jumped to 3,800-5,550 hours in identical service.

Over 100 sizes in both round and rectangular pots are available for production from stock patterns. Write for Bulletin T-205, listing shapes and sizes available. Electro-Alloys Division, 2097 Taylor St., Elyria, Ohio.

Specify THERMALLOY® for heat and abrasion resistance... CHEMALLOY® for corrosion resistance

®Reg. U. S. Pat. Off.

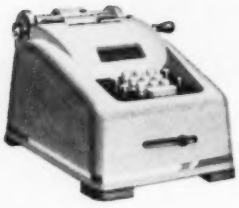
AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

MAGNESIUM

and the problem of

COST



in your product

THE cost of any metal extends much further than just the cost of raw ingots. This is particularly true of magnesium, a metal that offers many economies from ingot to your finished product.

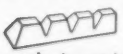
At the ingot stage, magnesium has an outstanding record of price stability. By its very nature . . . electrochemically extracted from unlimited sea waters at our own shores . . . that stability is inherent.

Then there is the cost of metal fabrication, a cost largely dependent upon fabricating knowledge and facilities. Perhaps no other metal has advanced so rapidly in fabricating techniques in the past ten years. Today, magnesium is produced in all common forms such as extrusions, sheet, plate or castings at prices generally competitive with other metals.

Within your own plant, magnesium offers many economies. It is one of the most machinable of all metals. It has excellent hot drawing qualities, permitting deeper draws than any other metal. And throughout your manufacturing and distributing processes, magnesium's light weight cuts the costs of transportation and handling.

But above all, magnesium cuts the competitive penalty of weight at the point of sale. Wherever a product is made to be moved, either by human or mechanical means, magnesium offers a real sales advantage, for it is the world's lightest structural metal . . . one-third lighter than the next lightest metal.

For your "Tomorrow's" Product . . .



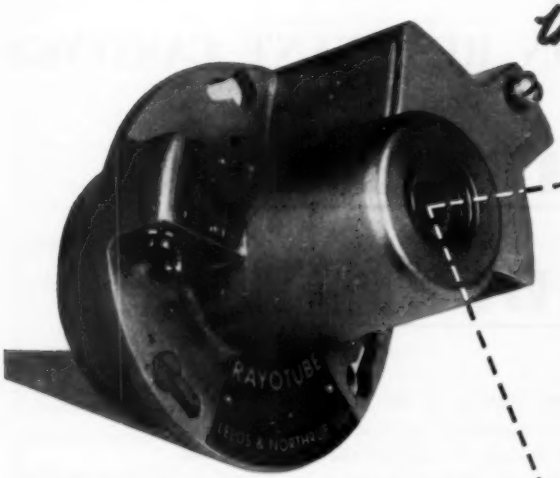
Today, magnesium is a tremendously important part of our defense effort, and like many other metals, is required in great quantities by the government. But in planning "Tomorrow's" production, remember this fact: the seas, at our own shores can provide 100 million tons of magnesium per year for 1,000,000 years without significantly reducing the supply!

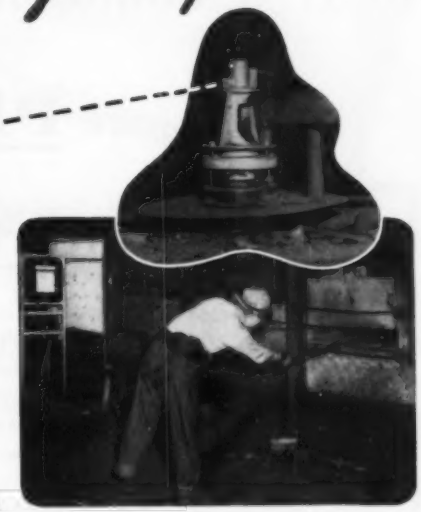
THE DOW CHEMICAL COMPANY

Magnesium Department • Midland, Michigan

New York • Boston • Philadelphia • Washington • Atlanta • Cleveland • Detroit
Chicago • St. Louis • Houston • San Francisco • Los Angeles • Seattle
Dow Chemical of Canada, Limited, Toronto, Canada

Can this new Rayotube mean better control of temperature in your plant?





In Henry Disston & Sons, Inc. plant, Rayotube in slab furnace roof needs no water-jacket against high ambient heat.

In spite of high ambient temperature, this Rayotube in roof of an open-hearth furnace has neither water-jacket nor air connection.

BUILT to detect temperatures for either Speedomax or Micromax Controllers, this new Rayotube No. 8890 has three features which help to improve the accuracy of control action.

1. The water jacket often needed for earlier Rayotubes is seldom required for this one because accuracy is not affected by ambient temperatures unless the head housing itself (shown above) exceeds 350 F. Omitting the jacket greatly simplifies installation and saves both water and maintenance due to water lines.

2. Overheating the Rayotube head to as high as 500 F does no harm; the accuracy decreases above 350, but returns fully as temperature drops. Thus, a few minutes' glare from an open furnace door does not affect the instrument's usefulness.

3. New, quick-sighting optical system for aiming the Rayotube at area of important temperature is especially helpful when aiming down an open-end tube to measure directly the surface temperature of parts being heated.

Catalog N-33B describes all Rayotubes as well as Speedomax and Micromax Pyrometers; we also can send description of this Rayotube only. Kindly address either our nearest office, or 4927 Stenton Avenue, Philadelphia 44, Pa.

Jrl Ad NS3(2)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Metal Progress is published and copyrighted, 1951, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

HEAT & CORROSION RESISTANT CASTINGS

are PREFERRED

by INDUSTRY

Behind the identity of an ACCOLOY trademark are years of engineering and research. The improved design of castings, the finer grain size, the close control of pouring and the multiple testing of the finished job are all points of superiority that so many manufacturers demand *and get* when they use ACCOLOY castings.

These ACCOLOY castings, job-proven on the production line, can produce more work of higher quality with fewer breakdowns and still give more net profit per dollar of capital investment.

Call your nearest ACCOLOY Engineer for an honest analysis of your High Temperature problems.

Producers of *Belts* *Chains* *Retorts* *Muffles* *Salt Pots* *Roller Rails* *Carburizing Boxes* *Trays and Fixtures*

ALLOY ENGINEERING AND CASTING COMPANY

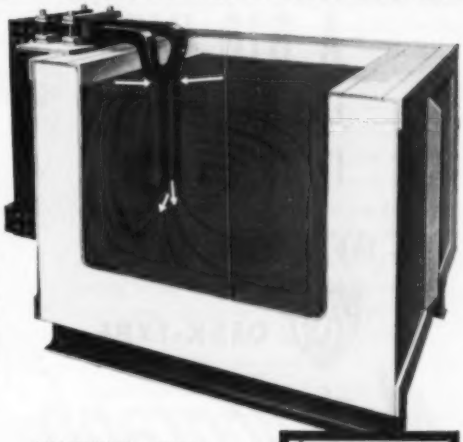
Alloy Casting Co. (Division)

Champaign, Illinois

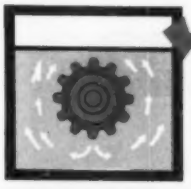
ENGINEERING IS PHILOSOPHY . . . GOOD ENGINEERING, PURE LOGIC

THE MOST EFFICIENT HEAT TREATING PRINCIPLE

...for CARBURIZING • CYANIDE HARDENING NEUTRAL HARDENING • ANNEALING OR HARDENING STAINLESS STEEL • BRAZING • HARDENING HIGHSPEED STEEL • AUSTEMPERING • MARTEMPERING • PROCESS ANNEALING • CYCLIC ANNEALING DRAWING (TEMPERING) • SOLUTION HEAT TREATMENT • DESCALING • DESANDING • CLEANING

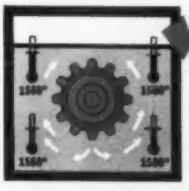


In the Ajax Electric Salt Bath, utilizing immersed electrodes, all heat is generated within the bath itself—the liquid salt acting as a "resistor". Electrodynamic forces produce vigorous circulation throughout the bath, in the *downward* motion indicated. This is precisely opposite to the *upward* thermal flow—dependent on a temperature difference in a bath—which exists in other salt bath furnaces. Only Ajax offers electrodynamic circulation!



RAPID HEATING BY CONDUCTION

The rate of heating depends only on the heat conductivity of the work itself. Thus, the Ajax Salt Bath Furnace heats work 4 to 6 times faster than a radiation type or forced convection furnace.



UNIFORM HEATING

The liquid salt completely surrounds the work and the automatic stirring action transmits uniform heat to all surfaces simultaneously. No other method delivers such heating uniformity—within 5° F. or *less* at any part of the bath.

NO ATMOSPHERE PROBLEMS

The Ajax Electric Salt Bath Furnace eliminates *all* atmosphere control problems. Scaling, oxidation and decarb are avoided. First cost of gas generating equipment as well as its operating expense are eliminated.

AUTOMATIC PREHEATING

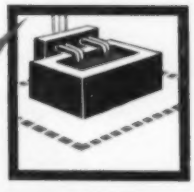
When a cold piece of metal is immersed, a "cocoon" of frozen salt forms around it instantly. This layer serves as a temporary insulator, preventing temperature shock and too sudden heating. The frozen salt melts in a minute or less and the work then heats rapidly to bath temperature.

BUOYANCY THAT MINIMIZES DISTORTION

Although the work sinks readily into the liquid salt, the bath nevertheless supports it to a marked degree. In effect, the work weighs appreciably less when immersed and this tends to prevent distortion and warpage.

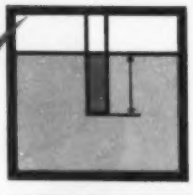
MORE PRODUCTION IN LESS FLOOR SPACE

Because an Ajax furnace heats work so much faster—and because it eliminates the need for atmosphere generators and similar bulky auxiliary equipment, a proportionately smaller amount of floor space is required to handle a given volume of work.



SELECTIVE HEATING

Because of its rapid heating rate, only that portion of the work immersed in the bath is heated. Just dip and treat *any desired portion* of any metal part or assembly.



NO SKILLED LABOR

Operation is so entirely automatic, so closely controlled by the Ajax furnace itself, that even an unskilled operator can handle full production.

72 pages of factual heat treating data! Write for Catalog 116 on your company stationery.

AJAX ELECTRIC SALT BATH FURNACES

AJAX ELECTRIC COMPANY, INC. 910 Frankford Ave., Philadelphia 23, Pa.
The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively

A BIG HIT EVERYWHERE IT IS SHOWN

. . the Outstanding New

DESK-TYPE

Metallograph

. . . and no wonder, for it introduces to metallographers so *much* that is completely new—new simplicity of operation, new convenience, new speed and accuracy. Everyone who sees the AO Metallograph takes the time to study it thoroughly, operate it, and become *convinced* that here is a radical advancement in the field of metals microscopy.

SIT DOWN AND STAY SEATED. From start to finish every control, every operation, is at your fingertips.

FOCUS QUICKLY, AUTOMATICALLY, ACCURATELY. Final focusing for photography is accomplished through the parfocal visual system.

UNBELIEVABLE SPEED AND PRECISION in changing magnification, adjusting lamp, making exposure, taking notes.

OTHER FEATURES: monocular or binocular bodies, revolving objective turret, 2 lamps — visual and photographic, perfect arc lamp performance with *both* AC and DC current, "autofocus" coarse adjustment stop.

Every user of metallographic equipment should *know* this AO instrument. For your copy of our descriptive 12 page catalog, write Dept. U119.

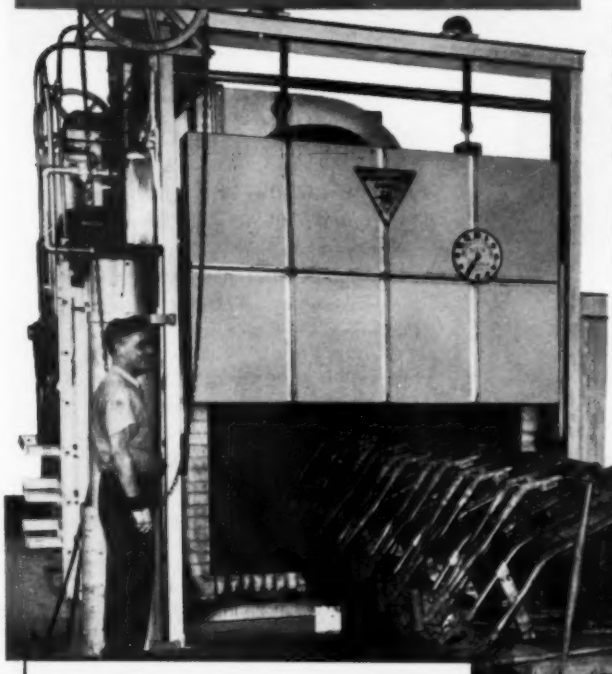
American Optical

INSTRUMENT DIVISION • BUFFALO 15, NEW YORK

Harley-Davidson meets higher production schedules

DESPATCH

New, Double-end ANNEALING FURNACE Boosts Production 60% over old Methods



THE NATION'S EXCLUSIVE BUILDER OF MOTORCYCLES HAS AGAIN CHOSEN DESPATCH EQUIPMENT . . . Most recent DESPATCH installation is this gas-fired, forced convection air heated type, double-end furnace for annealing motorcycle frames, forks, handlebars, brake shells, etc.

Only steel is handled by the furnace and according to the foreman in charge, the percentage of production increase over the old furnace is 60%. Time saving has been bettered some 60% also, because of the short heat-up period of 20 minutes as compared to an hour with the old furnace. Another time-saving feature is the fact that the furnace can be loaded from either end.

Better quality to meet the firm's rigid requirements has been achieved due to the accurate temperature control and heat uniformity the furnace provides. It is equipped with electrical and safety controls, and the direct gas-fired heater is capable of producing 1,300,000 BTU's per hour.

CALL ON DESPATCH

DESPATCH furnaces are engineered to fit any industry, any heat application. Write to Dept. P for more information.

FOLLOWING ARE MOTORCYCLE APPLICATIONS EMPLOYING THE NEW DESPATCH FURNACE

- *Frames** 850°, 1¼ hr., #1035 steel.
- *Safety Guards,* 750°, 1 hr., #C1026 steel.
- *Brake Shells,* 725°,*1 hr., #1010 carburized.
- *Connecting Rods,* 400°, 2 hrs., #1045 steel.
- *Hub Shells,* 400°, ¾ hr., #1010 steel.

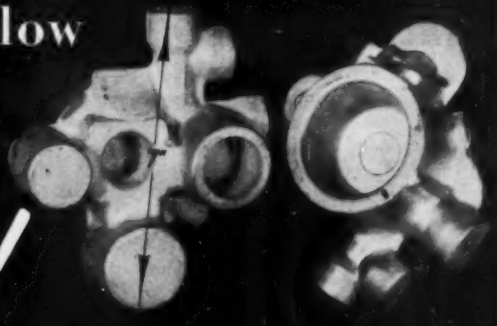
* The picture shows a load of motorcycle frames being pushed into the furnace for stress relieving; 15 per load, 5 loads per day.

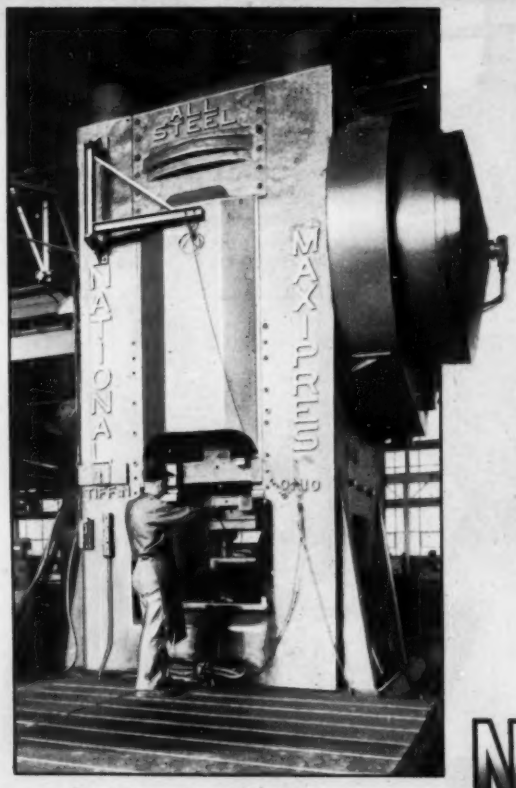
DESPATCH OVEN COMPANY

Minneapolis Office: 619 S. E. 8th St.

Chicago Office: 4554 Broadway

This Intricate Brass Forging Made in One Blow on a NATIONAL 6A MAXIPRES!





Forging operation at Mueller Brass Co., Port Huron, Michigan

● The Mueller Brass Co., Port Huron, Michigan, makes this difficult brass valve forging in only one blow at a rate of 300 forgings per hour on a National No. 6A MAXIPRES. The original billet measures 3-9/16 inches round by 5-7/16 inches long. (16.6 lbs.)

Successful master-forgers of brass and bronze, and pioneers in the development of specialized forging techniques, the Mueller Brass Co. relies upon the dependability of five MAXIPRESSES for a large share of its forging output.

If you have a forging problem—hot or cold, ferrous or non-ferrous—let us help you with it. Send us prints or a sample of the part you wish to forge. Better yet, visit us. No obligation.

NATIONAL
MACHINERY COMPANY
TIFFIN, OHIO.

DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES—MAXIPRESSES—COLD HEADERS—AND BOLT, NUT, RIVET, AND WIRE NAIL MACHINERY

Hartford Detroit Chicago

He's Not Ordering Steel—
But Nearly Everyone Else is

Let's be honest about it. We can't always fill all our customers' steel requirements. Our plant is producing every ton of steel in its capacity and we are doing everything we can to increase our facilities. Yet it's not enough. You know the situation as well as we do.

But we can and will continue to produce steel as fine as strict metallurgical control can make it. And we can and will continue to be completely honest about our ability to deliver. When we promise delivery, you can be sure your order will be shipped as promised, in the specifications and with the quality you have always expected from us.

INTERNATIONAL HARVESTER

WISCONSIN STEEL COMPANY, affiliate of INTERNATIONAL HARVESTER COMPANY
180 North Michigan Avenue, Chicago 1, Illinois

WISCONSIN STEEL

Ajax-Northrup Induction Melting

"NO OTHER METHOD GETS SO MUCH OUT OF THE MOLTEN METAL"

Says I. E. Waechter, Chief Metallurgist, Alloy Precision Castings Company.

Users from all over the country praise the ability of Ajax-Northrup high frequency furnaces to give back what you put into them . . . no alloy loss, no carbon contamination . . . no off-analysis melts. Even the most difficult analyses, high in chromium, tungsten, nickel, and other "hard-to-handle" elements, are reproduced in melt after melt with unfailing precision!

Recovery of oxidizable alloys is phenomenally high . . . 98.5% chromium recovery reported by one user, 70 to 80% vanadium recovery by another. Savings in alloying elements and deoxidizers alone give Ajax-Northrup a two-to-one advantage in a nickel steel plant.

Ajax-Northrup furnaces are available in sizes from an ounce to a ton for non-ferrous and precious metals, to 8 tons for ferrous metals. Motor-generator units from 25 to 1200 kw. and up. Self tuning, trouble-free spark-gap converters from 3 to 40 kw. Just name your alloys and quantities—we'll send you the proper technical bulletins—free.

AJAX NORTHRUP

HEATING & MELTING

Associate Companies

AJAX ELECTRO METALLURGICAL CORP.
AJAX ELECTRIC FURNACE CORPORATION
AJAX ELECTRIC COMPANY, INC.
AJAX ENGINEERING CORPORATION

127

AJAX ELECTROTHERMIC CORPORATION • AJAX PARK • TRENTON 5, NEW JERSEY

ACID ADDITION AGENT

Stops fuming of acids — promotes better wetting — lowers drag-out — saves acid — less harm to operator — less corrosion on surrounding equipment — more uniform pickling effective with sulphuric acid hot and cold — hydrochloric — phosphoric — hydrofluoric acids.

COMPOUND 42

A new cleaning and pickling agent combined—removes oil and rust at room temperature in *One* operation — prepares metals for painting — inhibits rusting — apply by dipping or brushing.

INHIBITOR 8

A new complete inhibitor to stop attack on base steel — high inhibition in sulphuric—hydrochloric—phosphoric acids —lowers surface tension—less drag-out —saves acid—reduces rusting after pickling — reduces fuming — bright pickling — makes pickling a more pleasant and healthful operation.

COMPOUND NR-37

Prevents rusting during drying but *leaves no* residue — added to hot or cold water it permits drying without rusting and leaves steel clean for painting — very effective for porous castings.

ENTHONE INCORPORATED

442 ELM STREET • NEW HAVEN, CONNECTICUT

Write for Check List
Sixty Products and Processes
for Metal Finishing

Enduro®

TAKES A "BITE" OUT OF HIGH MACHINING COSTS

● ENDURO Stainless Steel takes a shine to dentists.

In dental hand-pieces—precisely machined from ENDURO forgings—it retains its bright shining lustre despite day-after-day sterilizing. ENDURO instruments are sanitary; free from rust, corrosion and oxidation; tough and long-lasting.

ENDURO responds uniformly to forging—and, as these intricate parts indicate, is readily machinable.

In addition, ENDURO Cold Finished Bars—processed by Republic's Union Drawn Steel Division—provide close tolerances, accuracy of section, uniform soundness and fine surface finish. Two grades are approximately 90% as machinable as Bessemer screw stock. All these qualities combine to hold unit costs and reject losses for stainless steel parts to lowest possible levels.

Republic metallurgists and machining technicians are ready now to help you take large "bites" out of high machining costs through the proper application of ENDURO free-machining bars—both hot rolled and cold drawn. Write:

REPUBLIC STEEL CORPORATION

Alloy Steel Division • Massillon, Ohio

GENERAL OFFICES • CLEVELAND 1, OHIO

Export Department: Chrysler Building, New York 17, N. Y.

FOR TOP STEEL PRODUCTION...keep your scrap moving to the mills. Call your scrap dealer today.

Republic ENDURO® FREE-MACHINING STAINLESS STEEL

REPUBLIC STEEL

Other Republic Products include Carbon and Alloy Steels—Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

The Case of the Super Service

SERVICE IS A CLAIM TO FAME . . .

Just as the fine chef assures his patrons the choice cuts of beef, so does The McKay Company ensure its customers arc-welding electrodes which are second to none.

The McKay Staff stands in readiness at all times to give complete and efficient SERVICE —either technical or otherwise—on any situation which may arise in the use or selection of McKay Electrodes for arc-welding Mild Steels, Stainless Steels and Alloy Steels.

SERVICE . . . that's our meat and one of our big claims to fame.

McKAY
ARC-WELDING
ELECTRODES
For MILD, STAINLESS & ALLOY STEELS

Send for your copy of the new McKay Manual
THE WELDING OF STAINLESS STEELS

THE McKAY COMPANY
403 McKAY BUILDING
Pittsburgh 22, Pa.

BRASS AND COPPER WIRE CLOTH

Have you a "DO" order?

When you need Industrial Wire Cloth or Strainer Cloth for a Defense Order, your nearest Chase Warehouse is the place to inquire for it.

Chase Brass and Copper Wire Cloth is available in meshes from No. 2 to No. 100 and in varying gauges for a wide variety of industrial uses. The mesh is uniform and the wires double crimped to keep openings square and true.

One of the 23 Chase Warehouses or the four Chase Sales Offices will give you full information on the type of wire cloth best suited for your production problem. Send the coupon below for free Chase book describing the full line of Chase Brass and Copper Wire Cloth.

Chase BRASS & COPPER

WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION

• *The Nation's Headquarters for Brass & Copper*

Albany†	Chicago	Denver†	Kansas City, Mo.	Newark	Pittsburgh	San Francisco
Atlanta	Cincinnati	Detroit	Los Angeles	New Orleans	Providence	Seattle
Baltimore	Cleveland	Houston†	Milwaukee	New York	Rochester†	Waterbury
Boston	Dallas	Indianapolis	Minneapolis	Philadelphia	St. Louis	(†sales office only)

FREE Chase Book lists mesh, diameter of wire, per cent of open area, weight and other important data.

Chase Brass & Copper Co., Dept. MP 751
Waterbury 20, Conn.

Please send me your FREE book on Chase Brass & Copper Wire Cloth.

Name_____

Position_____

Firm_____

Address_____

City_____ State_____

we put our heads together with NEW PROCESS GEAR CO. over this heat treating problem...

AEROHEAT® 1200 reduces sludging and increases pot life 20%

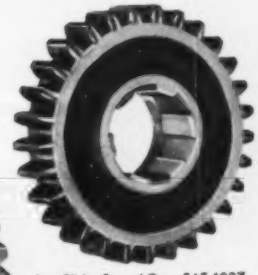
After pack carburizing gears, the New Process Gear Company of Syracuse, N. Y., was encountering undesirable sludging of the transfer salt. New Process engineers realized that a reduction in sludging would simplify processing considerably.

A Cyanamid service representative went into the problem with them. Together, they found a practical solution using Cyanamid's AEROHEAT 1200. Gears were pack carburized at 1680°F for eight hours to a case depth of .040". Then they were transferred to an AEROHEAT 1200 salt bath, held there 1½ to 3 minutes, and oil quenched.

Results? Sludging was minimized and pot life improved 15 to 20%.

Let Cyanamid technical service and heat treating compounds team up to help you meet high specifications required on defense and civilian contracts . . .

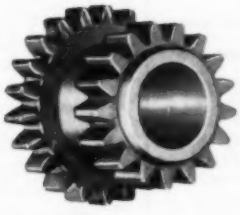
Next time, call Cyanamid first.



Low Slider Speed Gear SAE 4027.

Gear Transmission Main Shaft Third Speed SAE 4027.

Gear Transmission Main Shaft Fourth Speed SAE 4027.



Cluster Gear, like all other gears, hardened to 58-62 Rockwell C. SAE 4027.

Female TRACTA joint for universal SAE 4032.

Cyanamid's heat treating compounds include:

AEROCARB® Carburizing Compounds
AEROCASE® Case Hardening Compounds
AEROHEAT® Heat Treating Compounds

District Offices: Boston • Philadelphia • Baltimore • Charlotte Cleveland • Chicago • Kalamazoo • Detroit • St. Louis • Los Angeles
In Canada: North American Cyanamid Limited, Toronto and Montreal

MP7

AMERICAN Cyanamid COMPANY
INDUSTRIAL CHEMICALS DIVISION
30 Rockefeller Plaza, New York 20, New York

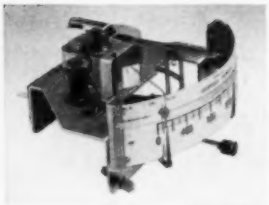
☐ Send technical data sheet on AEROHEAT 1200.
☐ Have technical service representative call.

*Name*_____ *Position*_____
*Company*_____
*Address*_____
*City*_____ *State*_____

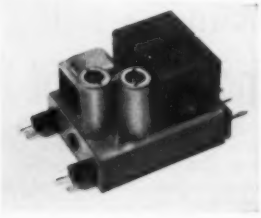
BROWN INSTRUMENTATION IS THE *Plus-Factor*

Now available

THE PYR-O-VANE WITH 3-POSITION CONTROL



Plug-in galvanometer measuring unit.



Plug-in electronic control unit.

Check These Outstanding Features:

- √ **COMPACT DESIGN**—*Requires only one amplifier and one set of vane coils. 9" wide x 10" high case, interchangeable for flush or surface mounting.*
- √ **INSTANTANEOUS CORRECTIVE ACTION**—*New high-resistance galvanometer and unique vane-type electronic control assure highest sensitivity with knife-edge control.*
- √ **PROTECTED GALVANOMETER & CONTROL UNITS** — *Separately enclosed. Practically immune to ambient temperature and humidity changes . . . less susceptible to vibration . . . withstands severe operating conditions.*
- √ **ADJUSTABLE NEUTRAL ZONE**—*Width of neutral zone adjustable from 1 to 5% of full scale. Set point index can be set at either end of neutral zone or anywhere within it.*
- √ **STANDARD TUBE**—*Uses standard 12AU7 tube. Can be purchased in any electronics store.*
- √ **SAFETY CHARACTERISTICS**—*"Fail-safe" design and thermocouple burnout feature protect work load.*

THE Pyr-O-Vane electronic millivoltmeter pyrometer has been acclaimed by industry in thousands of installations for its continuous, accurate control. Now, to further broaden its use, it has been made available with three-position control.

The three-position Pyr-O-Vane has the same advanced design features, and uses the same case as the popular two-position instrument. And it requires *only one amplifier assembly and one set of vane coils!* This means not only a more compact three-position controller, but a more economical one.

The instrument is ideal for control of certain electric or fuel-fired furnaces and ovens . . . for heating/cooling control . . . for delta-wye (Δ-Y) switch-over control . . . and for two-position control where a high limit control or alarm is desired. For further details write for Specification Sheet No. 114.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa.

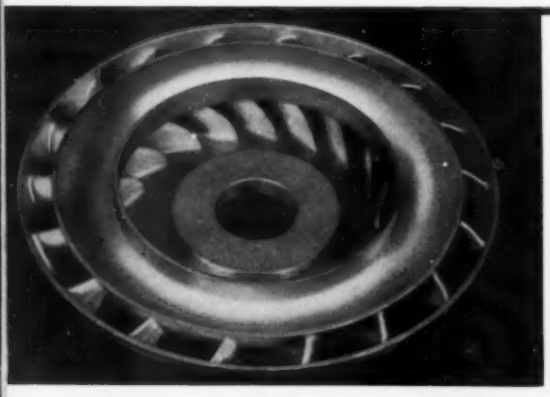
MINNEAPOLIS **Honeywell**

Brown Instruments

Aluminum

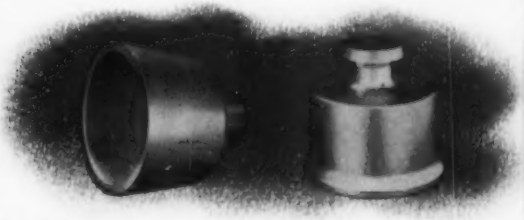
Government regulations limit the use of aluminum for other than essential products. The facts presented here are to help you speed this essential work and get the most out of available metal.

Alcoa is helping designers apply it to rearmament problems . . . with increased performance and savings in production and material costs.



CONTENTS

Aluminum Forgings — Magnesium
Aluminum Alloy Die Castings — Aluminum Fasteners
Finishing Aluminum — Aluminum Screw Machine Stock



Aluminum Forgings

Their low density and high tensile strength merit serious consideration for high-speed rotating parts.

High tensile strength alone is not sufficient to guarantee satisfactory performance of high-speed rotating parts. In any rotating part, the magnitude of stresses is directly proportional to the density of the material used. Thus the stresses in a heavy metal part are about three times greater than the stresses in an aluminum part.

Density also influences the power required to accelerate or decelerate the part. For example, if it took 8.7 horsepower to accelerate a 12″ disc of aluminum from 0 to 10,000 rpm in 10 seconds, it would take 24.8 horsepower to accelerate a similar steel disc under the same conditions. If the speed were to be increased from 0 to 20,000 rpm in the same time interval, the aluminum disc would require 35 horsepower — the steel disc, 100 horsepower.

Rotational stresses increase in proportion to the square of the speed. For example, if centrifugal stresses in an aluminum disc were 10,000 psi, the stresses in an identical steel disc would be 30,000 psi. If the speed were doubled, the stress in the aluminum part would be 40,000 psi and 120,000 psi in the steel disc.

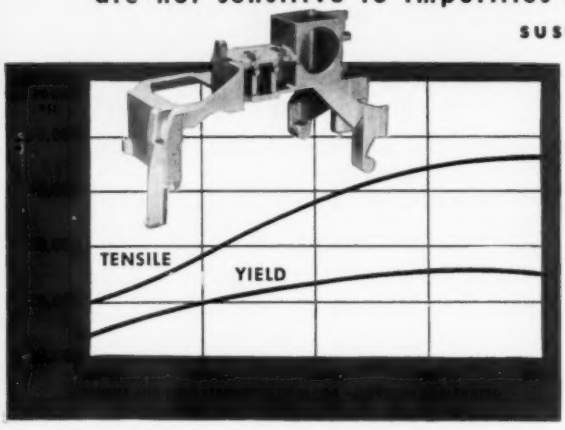
Because of Alcoa's wide experience in designing, forging and testing high-speed rotating parts, our specialists are exceptionally well-qualified to assist you in design and alloy selection. Basic design considerations are covered in Alcoa's 171-page book, "Designing for Alcoa Forgings." Write for your free copy.

ALCOA

ALUMINUM COMPANY OF AMERICA • 1805G GULF BLDG., PITTSBURGH, PA.

Aluminum Alloy Die Castings

are not sensitive to impurities . . . resist high temperatures and sustained loads when cast by Alcoa.



The strength and freedom from distortion inherent in Alcoa Die Castings result from aluminum itself. Unlike other commonly used die casting metals, aluminum is not sensitive to impurities — even when present in relatively large percentages.

Alcoa Aluminum Die Castings offer substantial physical property advantages. Stability of dimensions through a wide temperature range and under sustained loads. High conductivity of heat and electricity. None of these advantages can be matched by other die casting metals.

ALCOA DIE CASTINGS ARE AVAILABLE IN THREE TYPES OF ALLOYS

Aluminum-Silicon Series — (example No. 360) — Used mostly for large and complex castings. Produce castings of good soundness.

Aluminum-Silicon-Copper Series — (example No. 380) — Better machinability than alloys containing only silicon. Low-cost alloy.

Aluminum-Magnesium Series — (example No. 218) — Highest in strength, ductility and corrosion resistance. Easiest to machine. Most difficult to cast of all three. Most expensive of all Alcoa Alloys.

Alcoa specialists are listed under "aluminum" in your classified phone book. Let them help you with problems of alloy selection and other design details. Ask for the 188-page book, "Designing for Alcoa Die Castings."

Finishing Aluminum

Among the many finishes that aluminum takes are the chemical treatments. Decorative, functional, inexpensive.

Chemical treatments produce surface effects not possible by mechanical means, and in some cases are cheaper to use. Protective coatings, resistant to corrosion, may be applied by chemical treatment. The following brief description of each process will indicate which finish might suit your product best. For detailed information, Alcoa offers a new 63-page book, "Finishes for Alcoa Aluminum." Ask for your free copy.

THESE ARE SOME OF THE CHEMICAL FINISHES

Frosted — Has an attractive silvery appearance like finely etched glass. It is useful for finishing small or intricately-shaped parts not adapted to mechanical finishing methods. Frosted finishes should have the

ALCOA ALUMINUM ®

ALUMINUM COMPANY OF AMERICA • 1805G GULF BLDG., PITTSBURGH, PA.

Finishing Aluminum (continued)

permanent protection of an anodic treatment or clear lacquer.

Frosted finishes are applied by etching in a hot caustic solution, rinse, neutralizing in an acid solution, final rinsing and drying by air or on a steam table.

Etching — Extensive use of the etched finish is made in the manufacture of aluminum signs, name plates, dials for speedometers, vacuum gauges and the like. The areas which are not to be etched are protected by a layer of asphaltum. The article is then immersed in the etching solution, usually hydrochloric acid. After the work has been etched to a suitable depth, it is removed and rinsed. The background may be painted or anodized — then the asphaltum removed with an organic solvent.

Alrok finishes — Used to increase aluminum's resistance to corrosion and as a base for painted finishes. They are applied by treatment in hot alkaline solutions — are especially adapted to bulk treatment of small parts. Alrok finishes may also be used to minimize glare of aluminum roofing or siding.

Chemical brightening — A newly-developed treatment which leaves the surface extremely bright and clean. This new chemical finish must be protected by anodizing or clear lacquer, as it will become dull in time. For many aluminum products, chemical brightening is just as satisfactory and far less expensive than electro-brightening.

ALCOA
ALUMINUM COMPANY OF AMERICA • 1805G GULF BLDG., PITTSBURGH, PA.

Magnesium

Lighter, stronger by weight than most commercial metals, it offers remarkable cost-cutting opportunities to designers with imagination.

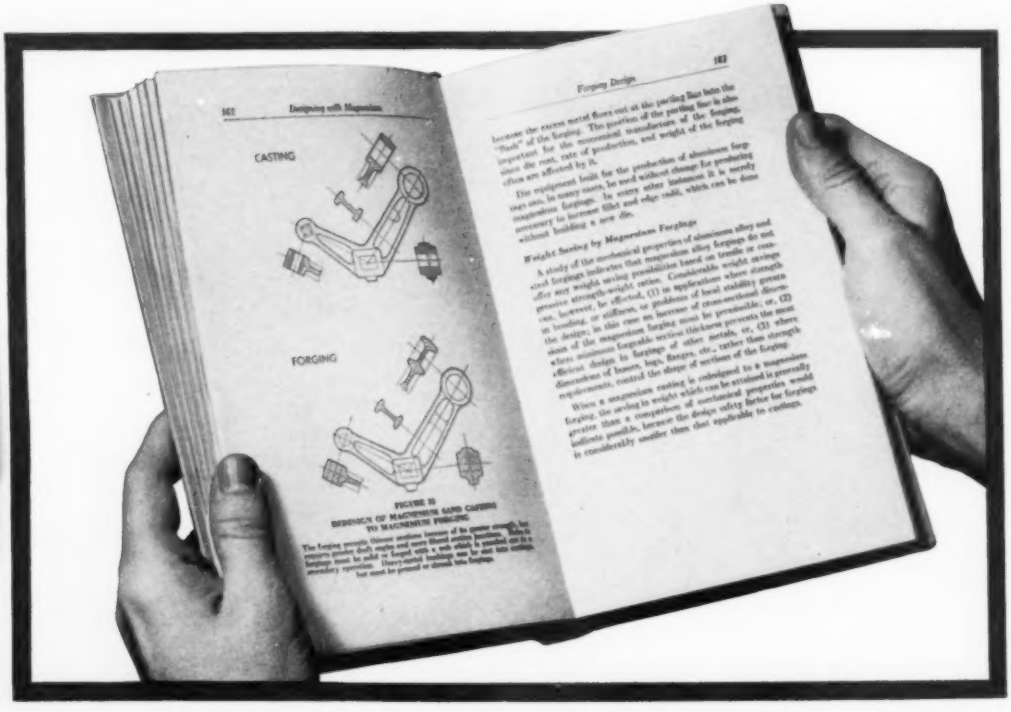
Perhaps you are fabricating complex structures which, engineered in magnesium, could be simplified, with resultant marked economies. As an illustration of possibilities in this direction, take the aircraft industry, where magnesium is widely used. An airplane wing is a load-bearing structure subject to vigorous requirements of strength, stiffness and light weight. Aircraft designers are experimenting *successfully* with wings and wing sections cast in one piece from magnesium. They are doing this to reduce weight, to gain strength, to increase rigidity, to cut costs. They have made a 69% reduction in the number of separate parts and 62% in the number of fastenings. In a single wing, this amounted to 1,132 fewer parts — 26,700 fewer fastenings.

Project your own designs for a moment in terms of fewer parts, fewer fastenings, fewer drawings, fewer supervisory hours. Think of savings in tools, materials and engineering — of faster production.

Perhaps castings wouldn't solve your problem. How about magnesium forgings? Or magnesium extrusions? Properly designed, magnesium extrusions can also reduce the number of parts or simplify an assembly. Maybe your bottleneck is machine capacity. Speeds and feeds are limited only by the capacity of the machine tool when cutting magnesium.

Your local Alcoa specialist, listed under "aluminum" in the classified phone book, will gladly help you evaluate magnesium's advantages for your designs.

Ask for a copy of "Designing with Magnesium" — a 329-page engineers' handbook.



ALCOA

ALUMINUM COMPANY OF AMERICA • 1805G GULF BLDG., PITTSBURGH, PA.

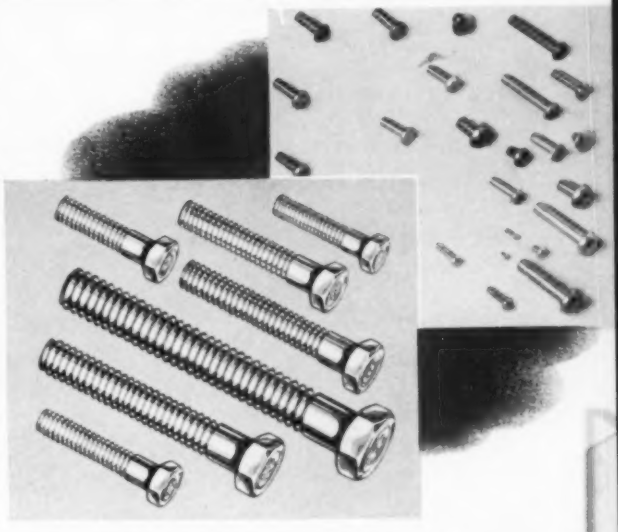
Aluminum Fasteners

Two new additions to the line of lowest cost corrosion-resistant fasteners offer substantial savings in joining.

Heavy-duty rivets — Alcoa has developed a new high-strength rivet for hot driving in heavy-duty aluminum structures. Now being offered for commercial applications on an experimental basis, it has an average shear strength of 38,000 psi. It can be driven with a pneumatic hammer in sizes up to 1". It offers good resistance to corrosion.

This high-strength rivet will reduce the number of rivets per joint — save greatly in fabrication costs — substitute for steel in many applications.

New economy bolt — A new, upset hex-head bolt priced only slightly higher than ordinary machine screws has been developed by Alcoa. It is available in sizes from 10-24 to $\frac{3}{4}$" – 10. Like other fasteners in the Alcoa line, it is made of high-strength Alcoa 24S-T4 Alloy. Threads are class 2, free fit, and conform to ASA specifications.



Aluminum Screw Machine Stock

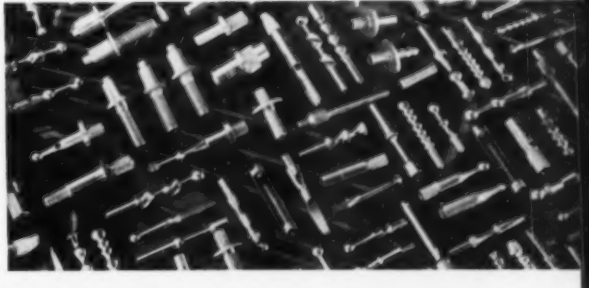
Designers looking for proof of durability of Aluminum Screw Machine Parts can find it in almost any smoking pipe.

That little filter in the stem of most smoking pipes can tell you many things about aluminum screw machine products.

These filters are made by the thousands. And from every pound of aluminum rod, pipe manufacturers get three times as many parts as they would from a pound of heavy metals. So when you divide aluminum's price per pound by three, it becomes less expensive than most metals.

Then when you consider that these filters live in a hot, moist, corrosive atmosphere, you see another advantage of aluminum — it lasts. In many pipes, the aluminum filter threads into an aluminum part in the pipe bowl. And while these threads must be air and water tight, they never seize or stick.

In fact, whole pipes are made of aluminum screw machine stock. They're light and their heat conductive properties give a cool, sweet smoke. Their lasting good looks give them extra buy appeal. Inexpensive, corrosion resistant, light, conductive of heat and electricity — no other metal combines these properties so well. Alcoa specialists, listed under "aluminum" in the classified phone book, offer their services in helping you use aluminum in your rearmament plans.



ALCOA

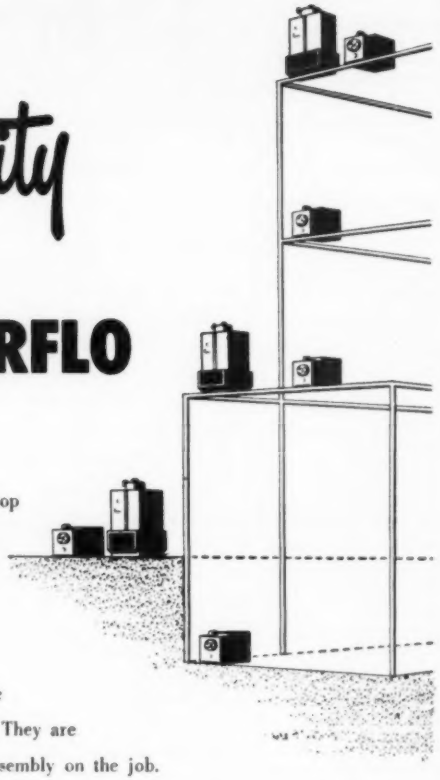
ALUMINUM COMPANY OF AMERICA • 1805G GULF BLDG., PITTSBURGH, PA.

any location any capacity

Just name the place . . . and

AQUATOWER or VAIRFLO

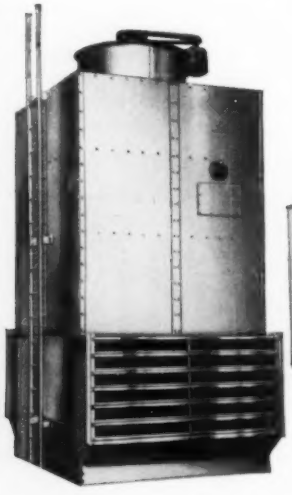
will do the water cooling job!

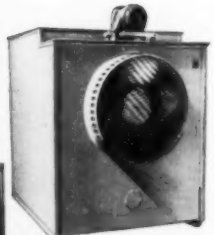


Indoors or out . . . on the ground or on the roof . . . on the top floor or in the basement—*there's a Marley cooling tower designed to fit any location and any cooling requirement.*

If your job is in the 3-ton to 60-ton range, you need an adaptable Aquatower—the compact, trouble-free cooling tower for indoor or outdoor use. Aquatowers are made in nine sizes and two styles to do each specific job economically. They are shipped completely assembled or "knocked-down" for easy assembly on the job.

In larger capacity installations the answer is a versatile Marley Vairflo . . . a broad range cooling tower with all the quality "extras" ordinarily found only in heavy-duty, high priced towers. The Vairflo, in steel or wood, harmonizes with architectural design. All material in Vairflos is completely prefabricated for simple job erection.





Whatever your need, select a Marley tower backed by the Marley guarantee and the "know-how" gained in more than 25 years of leadership in the water cooling industry. For more information, write for Marley bulletins AQ-51 and V-51, or call the Marley representative in your city.

also producers of
DOUBLE-FLOW TOWERS
CONVENTIONAL TOWERS
DRICOOLERS
NATURAL DRAFT TOWERS
SPRAY NOZZLES

The Marley Company, Inc.
KANSAS CITY 15, KANSAS

MARLEY

Up to 35% greater production, much longer tool life

with GULF "LASUPAR" and "ELECTRO" CUTTING OILS

Why have users of the new Gulf sulphurized cutting oils been able to step up feeds and speeds on tough machining jobs? Because, thanks to a special Gulf process of combining sulphur, Gulf Electro and Lasupar Cutting Oils provide greater sulphur activity over the entire range of a cutting operation.

This intensified chemical action insures better protection for the tool at elevated production rates—helps reduce built-up edge, prevents chip welding, prolongs tool life.

Because Gulf Electro Cutting Oil contains a larger percentage of this extremely active sulphur ingredient, it is recommended for the toughest machining jobs, where production and tool life are problems.

Gulf Lasupar Cutting Oil also contains stable sulphurized fatty oil, effective in producing the fine finishes for which this quality cutting oil is so well known.

Operators everywhere welcome the new Gulf Lasupar and Electro Cutting Oils—because they get all these production advantages without the disagreeable odor ordinarily associated with sulphurized cutting oils.

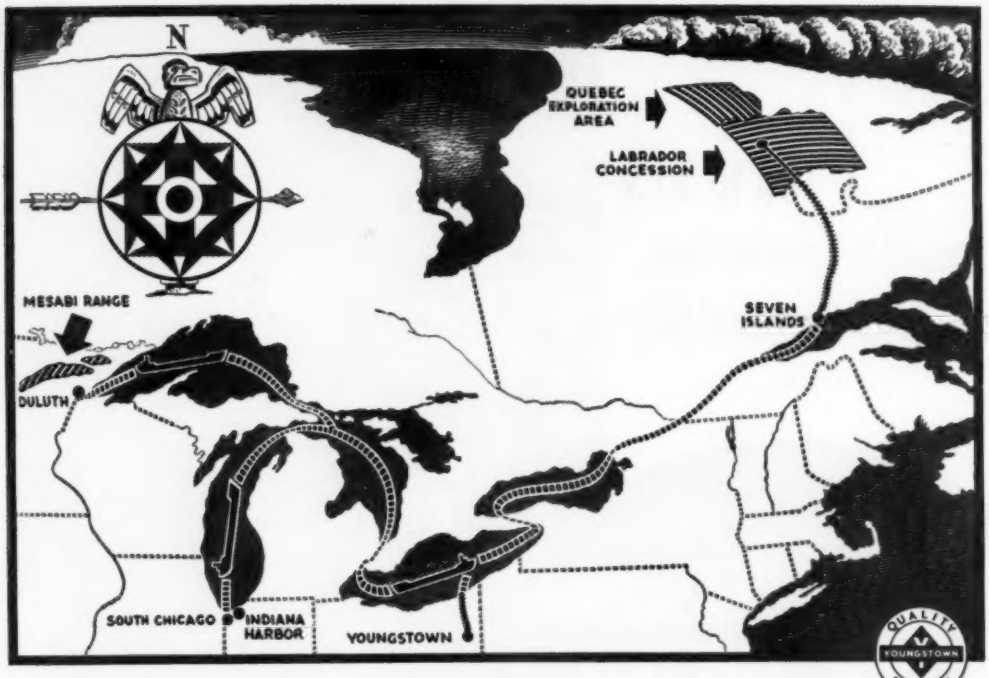
Call in a Gulf Lubrication Engineer today and arrange to use these outstanding oils in your shop. Or send the coupon below for additional information.

FIFTY YEARS OF SERVICE
1901 GULF 1951
PETROLEUM AND ITS PRODUCTS

Gulf Oil Corporation · Gulf Refining Company MP
3-SZ Gulf Building, Pittsburgh 30, Pa.

Please send me, without obligation, a copy of each of your new pamphlets "Gulf Lasupar Cutting Oil," "Gulf Electro Cutting Oil."

Name .....
Company .....
Title .....
Address .....



Mister, can you spare Half a Billion Dollars?

ONE half a billion dollars may seem like pin money compared to the sums mentioned for our national finances.

But it is more than three dollars for each man, woman and child in the United States. It is more than the entire steel industry earned in the "dreadful decade" from 1930 to 1939. It's more than America spent to win two wars--the War of 1812 and the Mexican War, combined.

Approximately one half a billion dollars is the estimated sum that a group of steel and mining companies, one of which is The Youngstown Sheet and Tube Company, is investing to guarantee future iron ore supplies for America. In the Mesabi iron range of Minnesota, development projects are under way which will produce millions of tons of iron concentrates from taconite. In Labrador and Quebec, a vast deposit of high grade ore is being developed. Plans include building a 360-mile railroad into the wilderness to ore docks on the St. Lawrence River.

Where does this money come from? From an unnoticed addition to our national debt? From "extra nickels" tucked away in the Federal budget? From more taxes levied on every citizen's income? *Certainly not!* Development of these ore reserves will be financed by each participating Company asking its shareholders to share in its tremendous cost.

America, in peace or in war, is served--now --and for generations to come. This is free enterprise. This is the system that created America from a wilderness and is the only sure way to keep it vigorous and strong.

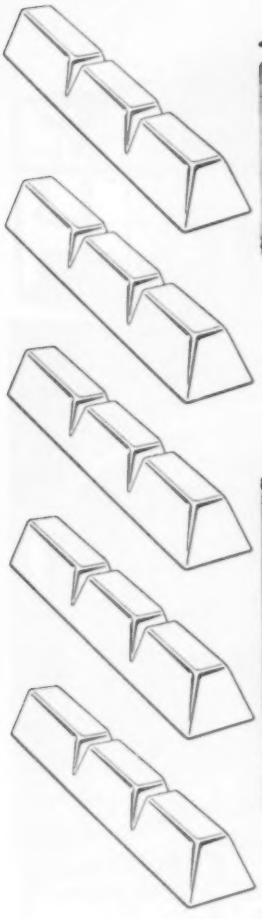
Scrap Metal is Critical Again

The Youngstown Sheet and Tube Company

General Offices--Youngstown 1, Ohio
Export Offices--500 Fifth Avenue, New York

MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

The steel industry is using all its resources to produce more steel, but it needs your help and needs it now. Turn in your scrap, through your regular sources, at the earliest possible moment.



in the Christiansen research lab...

the QUANTOMETER puts quality control at EDCO fingertips

The Quantometer was designed and built to EDCO requirements and is of the latest design and advancement in such equipment.

To assure you of the finest aluminum casting alloys, Christiansen Corporation has installed a Quantometer to record complete and exact alloy composition. It ensures a uniformity and quality of ingots throughout the "making of the heat" because its amazing speed enables constant sampling. It eliminates the margin for human error with an accuracy surpassing the most skilled team of chemists. It provides a graph recorded analysis of sixteen different elements—in less than three minutes.

Addition of the Quantometer to the Christiansen laboratory is further evidence of their desire to furnish you with ingots compounded to a degree heretofore thought impossible.

If you have a problem concerning aluminum alloy ingots, let a Christiansen expert help you—no obligation, of course.

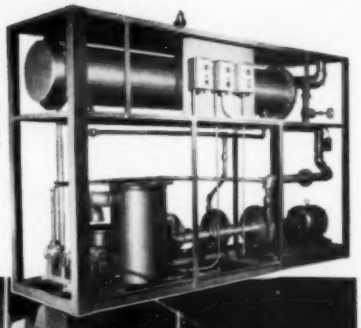
The name EDCO assures quality control

Christiansen Corporation

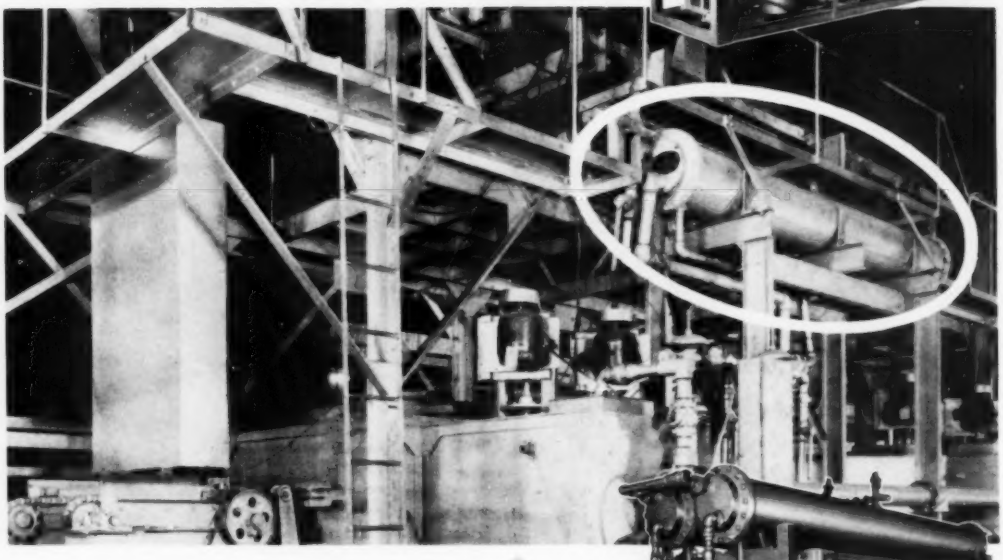
1515 N. KILPATRICK AVENUE - CHICAGO 51, ILLINOIS

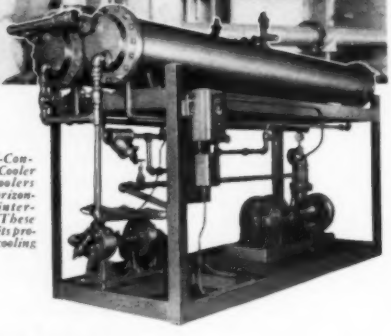
Hydro-Flo OIL QUENCHING SYSTEMS

Engineered to your requirements



Built-in B & G Kleen-Well Oil Strainer on this unit keeps oil free of scale without frequent cleaning.





B & G Self-Contained Oil Cooler with two Coolers mounted horizontally and interconnected. These multiple units provide large cooling capacity.

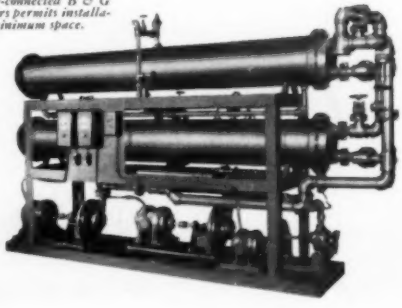
If you are having too many rejects because of warping or variations in quality, *look into your quenching methods!*

B & G *Hydro-Flo* Oil Quenching Systems are employed by manufacturers the country over, because of demonstrated ability to maintain desired characteristics in the finished product. Heated metal is brought down from furnace temperature to the correct end degree with unfailing accuracy. Each batch is quenched under *identical* conditions and hence is *identical* in quality.

Whatever your quenching problems, B & G engineers are ready to lend a hand. A complete system, including B & G Oil Coolers, Pumps, Strainers, Controls and Quench Tanks can be designed to fit your specific requirements. At your option, the system will be delivered as individual units or factory-assembled, ready for operation.

Write for information.

Vertical mounting of these two inter-connected B & G Oil Coolers permits installation in minimum space.



BELL & GOSSETT

COMPANY

Dept. CC-16, Morton Grove, Illinois

HEAT TREATING EQUIPMENT SINCE 1916

TOUGH...

- **Generous Sized Cabinets**
- **Conditioned Cooling System**
- **Built-In Checklite System**
- Oversized Components
- **Filament Voltage Regulation**
- **Industrial Type Tubes**

Oversized components built into every unit — industrial type tubes — extra heavy relays — sturdy insulators — in fact every part contributes to the extra value of the total — insuring uninterrupted production and hundreds of "bonus hours" of service life.

Yes, tough . . . and dependable! Lindberg Induction Heating Units are built to take punishment—like a well trained and conditioned champion, they absorb punishment under rigid production requirements far beyond the usual capabilities of induction heating equipment—and keep on giving dependable service . . . 24 hours a day . . . day after day.

In plants all over the country, these units are delivering a versatile, dependable service —on tiny pins—on mammoth ring gears —on thousands of other parts. Investigate the Lindberg Induction Heating Units— you will profit from their toughness... their ability to deliver 24 hour a day operation —day after day. Ask for Bulletin 1440.

LINDBERG *HIGH FREQUENCY DIVISION*

Lindberg Engineering Company, 2448 W. Hubbard Street, Chicago 12, Illinois

even a surge to full atmosphere can't hurt this team . .

DPi has combined the thermocouple gauge and the Philips gauge into a single instrument that's low in price, requires no special operating precautions, and covers the entire range from 2×10^{-5} mm. to 1 mm. Hg on a single meter.

The combination circuit uses three readily available radio tubes and three selenium rectifiers. It operates from any 115-v a-c outlet. No panel adjustments are necessary. All the operator does is turn it on and read the pressure. It can be calibrated, if needed, from the outside of the 10" x 8" x 8" cabinet. It's easily portable and requires no precautions against any pressure surges, even up to atmosphere.

The new Combination Thermocouple and Philips Gauge is one more step in DPi's continuing program to make high vacuum simple and inexpensive to create, measure, and use. We'll be glad to discuss your requirements in detail and quote specific prices. Simply write to: ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

The Philips gauge tube *contains a loop anode maintained at 3-kv d-c potential and permanent magnets to compress the electron paths. Its positive ion current is a measure of pressure over the range from .02 to 25 microns Hg.*

The thermocouple gauge tube *contains a junction to which heat is supplied at constant rate. Its temperature depends on heat loss by gas conduction, and is therefore a measure of pressure. It covers the range from 1 to 1000 microns Hg.*

high vacuum research and engineering

DPi

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry

Customer Reports:

ONLY 250 LBS. REJECTED OUT OF 2,000,000 WITH ASARCO CONTINUOUS CAST BRONZES!

A prominent manufacturer of railroad equipment reports: Only 250 lbs. of Asarco Continuous Cast bronze rejected out of a 2,000,000 lb. experience . . . better properties than other bronzes . . . scrap losses practically eliminated.

There are virtually no rejects when you use Continuous Cast bronzes. The unique Asarco casting process gives you bronze rods, tubes and shapes with fatigue and impact characteristics up to 100% better than those of sand cast bronzes . . . with better tensile strengths, yield strengths and hardnesses . . . with no porosity, no hard or soft spots. Asarco Continuous Cast bronzes are ideal for use on automatic screw machines.

You can get Continuous Cast bronzes made to order in a wide variety of alloys . . . in standard lengths of 12' . . . lengths 5' to 12' on request . . . lengths 12' to 20' on special arrangement.

216 sizes of the standard Asarcon 773 bronze (SAE 660) are stocked in 105" lengths for convenience at warehouses in principal cities across the country. Distributors will cut the warehouse stock to suit your specific requirement . . . *long or short.*

For more data see your Asarco distributor, or send the coupon for a 12-page color catalog that contains complete technical data.

ASARCO CONTINUOUS-CAST RODS TUBES SHAPES ®

West Coast Sales Agent:
KINGWELL BROS. LTD., 444 Natoma Street, San Francisco, Calif.

American Smelting and Refining Company
OFFICES: Perth Amboy Plant, Barber, New Jersey
Whiting, Indiana

American Smelting and Refining Company
Perth Amboy Plant, Barber, New Jersey

Please send me a free copy of the new 12-page catalog "ASARCO Continuous-Cast Copper Alloys."

Name..... Title.....

Company.....

Address.....

City..... Zone..... State.....

Airco Heliwelding process slashes costs...

EASILY JOINS THE "HARD-TO-WELD METALS"

Heliwelding is one of Airco's inert, gas-shielded, arc-welding processes that permits all-position welding of aluminum, magnesium, stainless steel, brass and copper.

Particularly in the lighter sections of these materials, this time-tested, easy-to-use process has proved most economical. Older methods generally require use of fluxes . . . but the envelope of inert gas that shields the weld eliminates the need for flux . . . no slag is formed, thus permitting the operator a clear view of the puddle resulting in welds that are of unexcelled quality with such smooth contours that finishing is reduced to a minimum. This means savings in time, trouble and money.

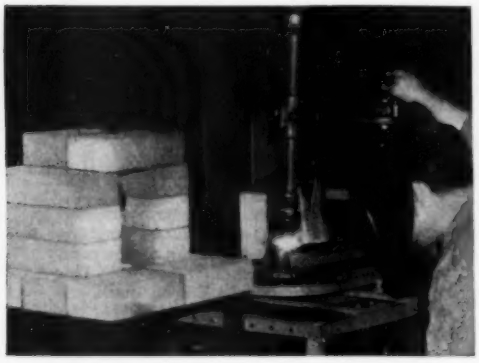
Furthermore, Heliwelding's special characteristics — the complete gas shielding of a non-consumable electrode — provide a highly efficient and concentrated arc, which, in turn, permits welding at exceptionally high speed.

Another outstanding feature of Heliwelding is its minimization of distortion. This is due to its high speed operation with a small diameter electrode. Heat is concentrated to a pin point and moved rapidly along the work . . . thin sections are easily joined and protected by the fact that such a small amount of weld metal is required.

The case studies shown on these pages give you some idea how this exceptional process could help you. While the facts may be startling, they could very easily be applied in your own shop . . . but find out for sure. Write . . . or phone your nearby Airco office. Ask for a copy of ADC-709: "Heliwelding — Catalog 9".

CUTS TIME AND MONEY COSTS . . . **Hinman Milking Machine Company of Oneida, N. Y., found Heliwelding's ability to join stainless steel without a flux ideally suited to the fabrication of pails to be sold in conjunction with their milking machines. Top quality pails were produced quickly and easily; machine finishing was virtually eliminated and polishing reduced to a minimum — tidy savings of money . . . and time.**

BUILDS A BETTER PRODUCT . . . **Ducate Brothers, of Little Ferry, N. J., used Heliwelding to speed production and save cost in the fabrication of copper tanks for hot water heaters. They found this outstanding process extremely fast — and resulting in smooth, high-type welds greatly increasing the quality of the finished product.**



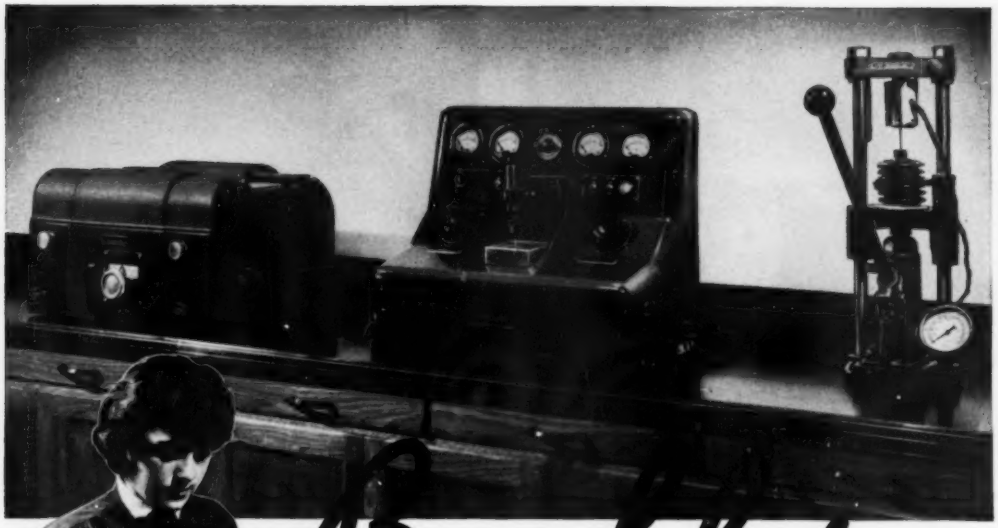
PERMITS MECHANIZED MASS-PRODUCTION . . . **Salkover Metal Processing Corp., of Long Island City, N. Y., adapted Heliwelding for mass-producing copper rotors for induction motors. Immediately production jumped to a new high, and costs dropped. Furthermore, Heliwelding permitted complete control of all operating variables — resulting in finer welds, with a minimum of rejects.**

ELIMINATES DISTORTION . . . **A prominent automobile manufacturer found Heliwelding most practical, both from a speed and finishing standpoint. Operating at 13″ per minute, Heliwelding produced a weld metal free from porosity and pinholes — distortion and splitting were completely eliminated on the .042″ sheet metal used to produce fender and similar assemblies.**

AIRCO

AIR REDUCTION

AIR REDUCTION SALES COMPANY • AIR REDUCTION MAGNOLIA COMPANY
AIR REDUCTION PACIFIC COMPANY
REPRESENTED INTERNATIONALLY BY AIRCO COMPANY INTERNATIONAL
Divisions of Air Reduction Company, Incorporated
Offices in Principal Cities



Buehler...

Operator using the new Model No. 1506 low speed polisher. Section of laboratory equipped with No. 1251 Duo Belt Sander—No. 1700 Electro Polisher—No. 1315 Press.

METALLURGICAL LABORATORY EQUIPMENT

. . . provides the metallurgist with the most complete line of modern designed precision machines for specimen mounting and preparation available anywhere in the world. This finely made equipment has been developed through a thorough understanding of the requirements of the metallurgist and a rigid insistance on perfection in the mechanical design and construction of each item.

Everything needed for metallurgical testing from cut-off machines, moulding presses, and grinders to the mechanical or electrolytic polishers is included in the Buehler line.

In setting up complete laboratories or adding items to present equipment the metallurgists will find in the Buehler line of coordinated equipment everything needed for producing the best work, with speed and accuracy.

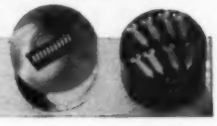
THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Write for bulletin of new equipment or information on any specific item. We invite correspondence relative to setting up complete laboratories suitable for any particular requirement.

Exclusive U. S. agents for Amsler and Chevenard Testing Machines.

Buehler Ltd.
A PARTNERSHIP

METALLURGICAL APPARATUS
165 WEST WACKER DRIVE, CHICAGO 1, ILL.

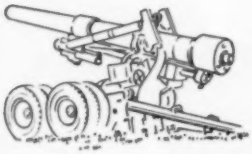


ARMAMENT COMPONENTS

FOR

TANKS • SHIPS

PLANES • GUNS



BRANDT'S ASSEMBLY LINES

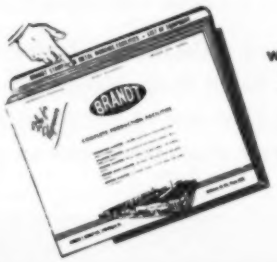
Are Geared For

PRIME & SUB-CONTRACTS FOR THE ARMED SERVICES*

Brandt has the right combination of facilities and experience to assure dependable, on-time deliveries of component parts on prime defense contract work regardless of size or quantity. Two modern plants, with 240,000 square feet of production lines for mass production of metal stampings, heavy weldments, general fabrication and complete assemblies . . . at your command!

Proximity to steel mills and rail and water transportation assures on-time delivery.

*Regardless of stepped-up defense production, our industrial accounts still receive prime consideration.

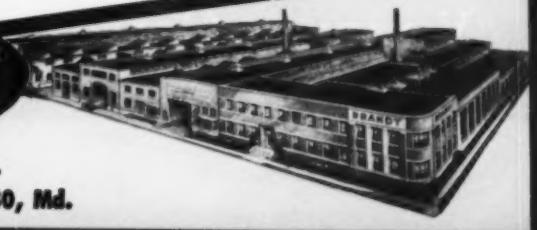


Write today on your company letterhead for handy file listing our complete production facilities.

STAMPINGS
WELDMENTS
SPOT WELDED ASSEMBLIES
PRESSED STEEL SHAPES
in
Stainless Steel, Carbon Steel, Aluminum and other alloys.

BRANDT

BALTIMORE



CHARLES T. BRANDT, INC.

1700 Ridgely Street, Baltimore 30, Md.

for

BORON STEELS

WITH FINE GRAIN SIZE

USE *Grainal* ALLOYS

Grain growth inhibitors in metallurgically determined amounts are included . . . in addition to boron . . . among the elements composing Grainal alloys.

Because of the beneficial influence of these additional elements, boron steels made with Grainal alloys maintain finer grain size at higher temperatures than is the case of boron steels made without inhibitors.

VANADIUM CORPORATION OF AMERICA

420 LEXINGTON AVENUE, NEW YORK 17, N. Y. • DETROIT • CHICAGO • CLEVELAND • PITTSBURGH

MAKERS OF ALLOYS

VANCORAM

CHEMICALS AND METALS

Engineering Digest

OF NEW PRODUCTS

CONTACT WHEEL: A new rubber contact wheel for abrasive belt polishing, developed by The Carborundum Co., makes possible increased production in those operations where glazing normally occurs. The relief angle, the wide spacing, and the narrowness of the lands are entirely new developments and are responsible for an in-

crease in belt life and cutting rates. Comparative tests, made on a belt backstand grinder of all known types of rubber contact wheels, demonstrated that average belt life was increased from 1.8 to 5 times, and belt life for very heat-sensitive work from 1.7 to 3.8 times. The contact wheel has been tested in the flat-surface grinding of auto bumpers prior to forming and on jobs where extremely soft buff-type or compress-canvas contact wheels are now in common use. In addition to producing longer belt life, higher stock removal rates, and a more uniform finish, the new wheel reduces the number of belt changes and reduces operator fatigue.

For further information circle No. 1 on literature request card on p. 32B

RECORDING VOLTMETERS AND AMMETERS: The "Series 500" electric recorders being manufactured by The Bristol Co. make a continuous record of voltage or current on an 8-in. circular chart. They feature a new measuring mechanism which produces a high actuating torque at a low electrical burden. The mechanism has shock-protected precision stainless steel bearings, magnetic damping, and a locking device to prevent damage due to rough handling. The instruments are housed in a compact die-cast aluminum alloy case and come in a variety of models.

For further information circle No. 2 on literature request card on p. 32B

INDUCTION HEATER: General Electric has announced an improved electronic-type 20-kw induction heater for use in high-speed annealing, brazing, hardening and soldering. Designed so that only the control and accessories required for a particular heating application need be purchased, the heater has totally enclosed steel cabinet equipped with dustproof doors. In addition to water cooling, blowers recirculate cooling air. All components are located within the cabinet so as to be easily accessible for maintenance. In addition, long-scale, switchboard-type instruments provide improved readability. The heater is available in two models — for short-run and long-run production. Units are available for operation on 230, 460, or 550-volt, three-phase, 60-cycle power supply.

For further information circle No. 3 on literature request card on p. 32B

BORING, DRILLING, MILLING: Speeds from 10 to 1300 rpm. in fine increments through 45 changes provide a new single-spindle boring, drilling and milling machine with specific metal working advantages, according to the manufacturer, Giddings & Lewis Machine Tool Co. Six entirely new structural features have been added to the basic G. & L. machine: hardened ways on bed and saddle, single spindle, automatic positioning device, swiveling pendant control, rapid speed change, and cut-and-shaved hardened gears.

For further information circle No. 4 on literature request card on p. 32B

SCALE REMOVAL: One of the most difficult problems in production heat treating of steel forgings is the removal of furnace scale. Now the Pennsylvania Salt Manufacturing Co. is marketing a preheat chemical bath which completely removes this scale during quenching and has accounted for cost savings of 90% over previous methods used in industrial production. The bath is made up of a new product, Pennsalt SR-4, dissolved in weak muriatic acid and water. The product was developed from a practice originated at the Toledo, Ohio, and Pottstown, Pa., plants of the Spicer Manufacturing Div. of the Dana Corp. Pennsalt and Spicer researchers cooperated in the development and in laboratory and plant tests. The Pennsalt SR-4 bath requires no heating and is made up in ordinary rubber-lined tanks. Dipping baskets can be made of simple sheet iron. Parts covered with forging scale are immersed in the bath for 5 min. and then may be placed directly into heat treating furnaces or can be stored for later heat treating. Following the heating, the forgings are water quenched and tempered. In conventional operations, the tenacious furnace scale is then removed by sand or shot-blasting, but with the use of

the SR-4 bath, this process is eliminated in most operations. When the forgings treated with SR-4 are water quenched, the scale actually blasts off from all surfaces, leaving them clean for subsequent machining.

For further information circle No. 5 on literature request card on p. 32B

VACUUM SYSTEM: The new RCA Type EMV-5 vacuum system will serve such applications as evaporation of metals and salts, sputtering, applying metallic films, vacuum distillation, drying, preparation of specimens for electron microscopy, study of discharges in gases at low pressure and study of electrical and physical properties of materials at low pressures and in various atmospheres.

For further information circle No. 6 on literature request card on p. 32B

DYNAMIC MICROMETER: The new Electro Dynamic Micrometer, made by Electro Products Laboratories, consists of a conventional mechanical micrometer head with sensing unit, and an electronic cabinet that is used with a cathode-ray oscillograph. Direct reading from the micrometer head of the sensing unit makes calibration of electronic components unnecessary; calibrations in division of 1/10,000 in. are provided. The oscillo-

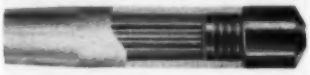
Engineering Digest

OF NEW PRODUCTS

graph will show a displacement versus time curve on the screen. All measurements are made without any physical contact between the sensing unit and the metal body. Measurements are independent of acceleration or frequency (rpm) of the displacement. The Dynamic Micrometer will accurately measure amplitude of dynamic movement at any speed to distances as small as 0.0001 in. Sensitivity is equal to 1% of total displacement.
For further information circle No. 7 on literature request card on p. 32B

WATER-SOLUBLE LUBRICANT: The commercial availability of Emulsifier STH, water-soluble, metalworking coolant lubricant for use in cutting, grinding, drawing, and stamping, has been announced by General Aniline & Film Corp. The product is being used with automatic chucking machines, hand screw machines, turret lathes, cylindrical and surface grinders, mechanical saws, drill presses and milling machines. Drawing and stamping jobs also are being performed successfully by dipping the sheet in diluted STH before working.
For further information circle No. 8 on literature request card on p. 32B

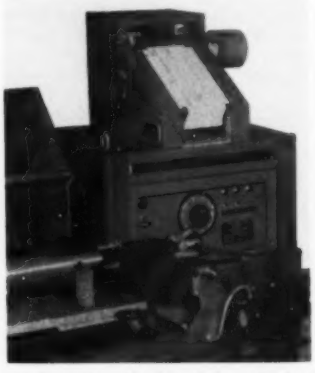
RESISTANCE WELDING ELECTRODE: A resistance welding innovation, the Mallory "Nu-Wrinkle Cap" electrode, is announced by P. R. Mallory & Co., Inc. The new electrode



reduces electrode costs without sacrifice in performance and conserves critical copper. It consists of a reusable shank and replaceable cap. When the welding face of the cap electrode is no longer serviceable, it is necessary to replace only the cap; the same shank can be used. A corrugated skirt provides positive electrical and thermal contact with the shank, while the fluted water hole in the shank assures maximum cooling efficiency. The electrode is a readily replaceable insert for resistance welding dies.
For further information circle No. 9 on literature request card on p. 32B

TOOL RE-DESIGN: Firth Sterling announces a complete re-design of their carbide-insert Mechanigript tools. The new line features open facing of the carbide insert so that chips curl against the carbide. Additional features of these tools include top or bottom screw adjustment of the insert. All styles will accommodate inserts made to the shape and size standards established by the Carbide Industry Standardization Committee.
For further information circle No. 10 on literature request card on p. 32B

AUTOMATIC CRACK DETECTOR: The function of Graydon Smith Products' Automatic Crack Detector for Tubes (A.C.D.T.) is to detect by magnetic means, and to record pictorially,



cracks and crack-shaped flaws in ferromagnetic tubular products. The inspection device travels through the bore of tubes, detecting and recording both surface and subsurface flaws. The speed of testing depends on the minimum size of the flaw to be detected. For example, cracks ¼ in. long in a 4-in. dia. tube require speeds around 4 linear ft. per min. A 1-in. crack would show up well at 15 ft. per min.
For further information circle No. 11 on literature request card on p. 32B

SMALL HYDRAULIC PRESSES: Two new hydraulic presses, a 5-ton and an 8-ton, are announced by Hannifin Corp. Typical applications include forming, bending, trimming, staking, riveting, and press-fit assem-

THOSE "OCTOPUS" FURNACE DAYS ARE GOING!

MEET JUMPIN' GIBBERIN' J.G. BROWN- THOSE ATMOSPHERE FURNACES GOT HIM DOWN -
NOW A DELAWARE FURNACE WITH SIMPLE CONTROLS - DOES EVERY JOB WELL AND TOOL PRODUCTION ROLLS!

DELAWARE TOOL STEEL CORP.
WILMINGTON 99, DELAWARE

Get the FACTS on the simple DELAWARE Controlled Atmosphere Furnace. One furnace does every heat treating job on every type of tool and alloy steel. No scale . . . No decarburization . . . No hokus pokus. Send for Bulletin F-1.

* * * STRAIGHT FACTS on Controlled Atmosphere are included in DELAWARE BULLETIN F-1.

Send for your copy today.

DELAWARE TOOL STEEL CORPORATION
WILMINGTON 99, DELAWARE

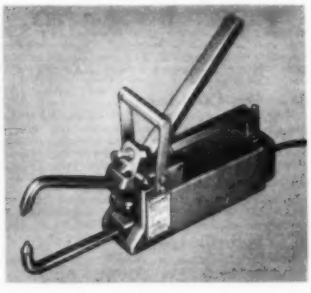
Engineering Digest

OF NEW PRODUCTS

bly work on production lines, as well as general-purpose or utility service when installed singly in large or small shops. Designated as the F-50A (5-ton) and the F-80 (8-ton), they are also offered with larger motor and pump and consequently higher ram speeds as the F-51 and F-81, respectively. The 10-in. stroke can be shortened by limiting the return stroke to the point where the ram just clears the work. Thus no ram motion and no productive time is wasted. The actual force exerted by the press can be adjusted anywhere in the range between 10 and 100% of maximum capacity, so the press will deliver the exact pressure needed, and no more, time after time.

For further information circle No. 12 on literature request card on p. 32B

SPOT WELDER: A heavy-duty portable spot welder, with a welding range up to $\frac{5}{8}$ in. combined thickness on mild and stainless steel or two pieces of 16-ga. galvanized metal, is announced by the National Cylinder Gas Co. This exceeds by 50% the $\frac{1}{4}$-in. capacity of the standard 110 and 220-volt models. Operating on 220-volt, single-phase, 50 to 60-cycle a.c., the new model is suitable for spot welding anywhere that sheet metal is fabricated or repaired. All models are operated with a toggle-action lever that locks the tongs on the work while the weld is being made. The lever can be adjusted for any thickness of metal in the range.



For further information circle No. 13 on literature request card on p. 32B

WELDING ELECTRODE: The development of a new welding electrode, the DH-4, is announced by Harnischfeger Corp. The electrode is heavily coated and leaves a negligible deposit of weld metal so that the fusion consists mainly of the parent metal. This electrode is produced in three sizes, $\frac{1}{8}$ in. for use at 300 amp., $\frac{5}{32}$ in. for use at 400 amp., and $\frac{3}{16}$ in. for use at 450 to 500 amp.

For further information circle No. 14 on literature request card on p. 32B

ROLL TEMPERATURE MEASUREMENT: A new roll surface temperature unit developed by Leeds & Northrup Co. measures temperature of a moving roll surface without touching the roll. It cannot scratch, score, or in any way destroy delicate surface films. Temperature is recorded automatically, and the recorder can be equipped to operate signals or controls. Applicable to roll diameters down to 9 in. and to flat surfaces, the new detecting unit operates independent of surface speed, emission charactcristics and finish. It can be mounted at the center of the roll or wherever actual temperature measurement is desired. This new primary element works on the principle that a moving object carries with it a thin, closely adhering layer of air nearly the same temperature as the moving surface. Mounted $\frac{1}{32}$ in. from the surface is a measuring head, contoured to fit the roll. A continuous stream of air is sucked past the measuring element and thus heats it to virtually the same temperature as the roll surface.

Although recorded temperature is a few degrees lower than true surface temperature, the difference remains substantially constant and is therefore negligible in process control (—4° F. or less).

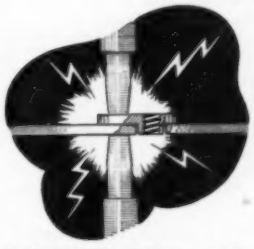
For further information circle No. 15 on literature request card on p. 32B

CUTOFF MACHINE: A new metal cutoff machine for low-cost cutting of ferrous and nonferrous metals at the rate of 4 sec. per sq.in. is now in production by Stone Machinery Co., Inc. The capacity of this new model is 1½-in. solids, 2½-in. pipe and structurals. Engineered with positive drive without the use of belts, the machine's full 3½-hp. geared-in-head motor delivers maximum constant power.

For further information circle No. 16 on literature request card on p. 32B

OHIO WELD NUTS

For economical Spot Welding



Ohio

SN Spotweld Nuts

No retapping required!

Thread sizes in stock

(Low Carbon Steel)

No. 6-32 to ⅜-24

Stainless Steel sizes made to order in production quantities.

For dependable Projection Welding

Ohio

WS Square Weld Nuts

Thread sizes in stock

(Low Carbon Steel)

No. 6-32 to ½-20

No retapping required!

No burning or discoloration!

For samples and welding information, send to

THE OHIO NUT & BOLT COMPANY

25 FIRST AVE. **BEREA, OHIO**

YOUR HARDNESS TESTER . . .

IS ONLY AS GOOD AS THE DIAMOND IT USES

Standard "C" Diamond Cone $18.00 F. O. B. Detroit

Dependably accurate "Rockwell" testing results are obtained only when every part of your hardness testing equipment is made to precision limits. That is why a correctly designed diamond penetrator is of such great importance. Always specify CLARK Diamond Cone Penetrators, both for Standard and for Superficial "Rockwell" testing. They are accurately made to the proper size and shape; exactly formed by expert lappers. CLARK Penetrators are designed for use on all "Rockwell" type testing machines.

CLARK

TOMORROW'S ACCURACY TODAY

INSTRUMENT, INC.

10200 FORD ROAD

DEARBORN, MICH.

What's New

IN MANUFACTURERS' LITERATURE

17. Abrasives, Coated

Supplement 111 to "A Lecture Course on Coated Abrasives" provides a description of coated abrasives and illustrations of acceptable industrial applications. Also includes all of the war-born and war-tested developments in metal grinding and finishing. *Behr-Manning Co.*

18. Aircraft Design

New catalog of Speed Nut fasteners for aircraft lists all aircraft fasteners manufactured under Mil-N-3337 specifications which govern sheet spring nuts for all branches of the military government. *Tinnerman Products, Inc.*

19. Alloy Steels

New 16-page, pocket-size booklet entitled "Republic Alloy Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

20. Alloys, Fabricated

Catalog available showing cost-cutting fabricated heat treating equipment for higher payloads and better quality. *Rolock, Inc.*

21. Aluminum

Copy of "Alcoa Aluminum Impact Extrusions" will be sent on request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

22. Aluminum-Bronze Alloys

New 4-page folder gives brief descriptions of Ampco aluminum bronze alloys recommended for corrosion applications, along with their physical properties and a guide to chemical agents. *Ampco Metal, Inc.*

23. Aluminum Forgings

To help you in designing for aluminum forgings, a new book is offered, covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Also a section on metallurgy gives all commercial alloy compositions, physical properties and tolerances. *Aluminum Co. of America.*

24. Aluminum Welding

New control system that extends electrode life for spot welding aluminum, fully described in "Technical Advisor No. 15". *Reynolds Metals Co.*

25. Arc Welding

Heliwelding. Airco's inert, gas-shielded arc-welding process for all-position welding of aluminum, magnesium, stainless steel, brass and copper is fully described in ADC-709 Catalog 9. *Air Reduction Sales Co.*

26. Atmosphere Control

Descriptive bulletin gives full information on furnace atmosphere indicator that works on the principle of relative thermal conductivity of gases. *Claud S. Gordon Co.*

27. Belts, Metal

Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

28. Camera, High Speed

"Magnifying Time", a new folder describing high-speed camera capable of 1000 to 3000 pictures per second. Particularly adaptable for close inspection in machine tool operations and also for measuring flow of liquids as in chemical mixers, coolant flow, etc. *Eastman Kodak Co.*

29. Carbide Die Sections

16-page booklet, "Diecarb—Grades, Applications, Design and Maintenance", is a new technical data booklet covering the use of sintered carbide in blanking dies. *Firth Sterling Steel & Carbide Corp.*

30. Castings

Bulletin 150 describes a broad range of component machine parts and assemblies produced by the centrifugal casting method. Covers nonferrous metals including all bronzes, monel metal, nickel, aluminum and special alloys. *Shenango-Penn Mold Co.*

31. Castings

Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

32. Castings, Nonferrous

Armetol, improved impregnant for magnesium alloy, aluminum bronze and other nonferrous castings is described in bulletin 501. *Archer-Daniels-Midland Co.*

33. Castings, Nonferrous

16-page anniversary book, "The Lavingot", Vol. 6, No. 3, furnishes an interesting picture story of 50 years of outstanding contributions to the nonferrous metal industry. Also gives tabular information on nonferrous casting alloys and helpful notes on foundry practice. *R. Lavin & Sons, Inc.*

34. Castings, Steel

New bulletin describes Pyrasteel, the chromium-nickel-silicon alloy for resisting oxidation and corrosion up to 2000°F and for withstanding most concentrated or dilute commercial acids and corrosive gases. *Chicago Steel Foundry Co.*

35. Cast Monel

New bulletin contains valuable information concerning production of cast Monel and wide range of desirable physical and mechanical properties obtainable. *Cooper Alloy Foundry Co.*

36. Cleaning Brushes

New booklet shows complete line of brushes and actual case histories of how they provide thorough cleaning of red-hot castings in 30 seconds. *Pittsburgh Plate Glass Co., Brush Div.*

37. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

38. Controller

Specification sheet 114 illustrates the Pyr-O-Vane millivoltmeter in a new model featuring three-position control. Requires only one amplifier assembly and one set of vane coils. Ideal for certain electric or fuel-fired furnaces and ovens, for cooling and heating and delta-wye switch-over control. *Minneapolis-Honeywell Regulator Co.*

39. Copper Alloys

Bulletin B-39 describes Formbrite copper-base alloys, specially processed with superfine grain and hard surface for cold-working of brass in sheet, strip or wire. *American Brass Co.*

40. Copper Alloy Tubes

An extensively illustrated 32-page brochure, "Life Extension for Condenser Tubes", deals with causes of corrosion and means of combating them, as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

41. Corrosion Notebook

16-page "Corrosion Notebook" contains data on corrosion resistance of various types of stainless tubing and pipe. Also provides data by type of corrodent at various concentrations and general types of corrosion. *Carpenter Steel Co.*

42. Cutting Oil

New bulletin on "Gulf Electro Cutting Oil" which contains larger percentage of active sulphur ingredient, recommended for toughest machining jobs. *Gulf Oil Corp.*

43. Detergent Cleaners

Bulletin, "Solubilizing Cleaners", describing action of new cleaners which will dissolve not only water-soluble soils but also water-insoluble soils that can normally be removed only by organic solvents; for instance, buffing compounds, greases and pigmented drawing compounds. *Pennsylvania Salt Mfg. Co.*

44. Die Cushions

New 20-page booklet catalogs entire line of die cushions with complete size, capacity and dimensional data. Also features series of cushion selection charts with photographs and drawings. *Danly Machine Specialties, Inc.*

45. Dry Cooler

Bulletin DC-50 illustrates complete line of DriCoolers in a wide range of capacities and designs for specific cooling jobs. *Marley Co.*

46. Ductile Iron

New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. *International Nickel Co.*

47. Dynamic Micrometer

New literature on an electro-mechanical instrument for measuring displacement, vibration or movement of a ferrous body to within 0.0001 inch. *Electro Products Labs., Inc.*

48. Electron Microscope

The new table model RCA electron microscope is described and illustrated in a 12-page booklet. *Radio Corp. of America.*

49. Emulsifier

Attractive, well-illustrated bulletin A-104 describes Emulsifier —Sth, the new coolant-lubricant for cutting, grinding, drawing and stamping. *General Aniline & Film Corp.*

50. Finishes

New 4-page two-color bulletin describes in detail the entire line of Iridite finishes for nonferrous metals. Also includes section on ARP process chemicals such as bright hardeners for zinc and cadmium plating and other specialties. *Allied Research Products, Inc.*

51. Forging

Information available on designing and
struction of forging and heat treating equip
for the production of all types of armat
Loftus Engineering Corp.

52. Forgings

New catalog 51 contains 30 pages covering
topics as type of forgings; where and how t
forgings; turnbuckle dimensions, strengths
related data. Well illustrated with tables
drawings. *Merrill Bros. Co.*

53. Furnace

New all-purpose furnace described in bu
HD-646 may be used for carburizing, nitri
dry cyaniding, bright annealing and clean ha
ing. *Hevi Duty Electric Co.*

54. Furnace

Full information furnished on new gas-at
phere high-production furnace for handling b
annealing of wire, strip and bar stock of cc
and nonferrous copper alloys. *Holcroft & Co.*

55. Furnace, Atmosphere

Bulletin F-1 gives full description of vers
controlled-atmosphere furnace for all steels
high carbon to high speed in range 1200 – 28
Delaware Tool Steel Corp.

56. Furnace Controls

Catalog N-33B describes all Rayotubes as
as Speedomax and Micromax pyrometers
economical and dependable temperature cor
Leeds & Northrup Co.

57. Furnaces

High temperature furnaces for temperature
to 2000°F are described in leaflet. *Carl-M*
Corp.

58. Furnaces

Bulletin 346 describes new electric muffle
naces designed to heat materials in an oxid
atmosphere for many research, toolroom and
duction operations. *Harper Electric Furnace*

59. Furnaces

Illustrated literature describes newest dev
ments in gas and electric heat treating furn
Westinghouse Electric Corp.

60. Furnaces

New bulletin 84P describes eight sizes in g
electric models as well as conveyorized and
or pot-type furnaces. *Despatch Oven Co.*

61. Furnaces

Complete "Buzzer" catalog available descr
Buzzer high-speed gas furnaces designed prim
for heat treating high carbon and alloy steels
also atmospheric pot hardening furnaces for
cyanide and lead hardening. *Charles A. Hones*

62. Furnaces, Heat Treatin

Bulletin SC-132 describes both radiant tube
direct-fired roller hearth furnaces as applie
heat treatments such as annealing, clean ha
ing, tubing, coils, disks and sheets. Also
for large and small parts as in shell cases. N
Combustion Corp.

63. Furnaces, Industrial

6-page folder describes 18 typical installa
of gas-fired and electric furnaces of various t
complete with specially designed equipment
bright annealing, scale-free hardening, ca
restoration, carburizing and production heat t
ment. *Electric Furnace Co.*

64. Graphite Heat Exchang

Reprint available on Graphite Heat Exchan
Made of Karbate impervious graphite, t
exchangers are used as boilers, coolers, conden
vaporizers and absorbers in handling corr
chemicals and can be ordered in complete
range. *National Carbon Co.*

65. Hardness Tester, Portab

Bulletin ET202 gives complete details on
Ernst portable hardness tester for direct at-th
readings of all metal types and shapes. *N*
International, Inc.

66. Hardness Tester, Portab

Illustrated circular describing the Ames port
hardness tester in sizes for work 1 inch to 6 in
round and flat. *Ames Precision Machine Wks*

67. Hardness Testers

Bulletin DH-114 contains full information
Tukon hardness testers for use in research
industrial testing of metallic and nonmet
materials. Also included is bulletin DH-7, gi
experiences in various fields. *Wilson Mecha*
Instrument Co.

68. Heat Treating

Ipsenlab periodic sheets show case historie
bright hardening, annealing and carburi
Ipsen Industries, Inc.

69. Heat Treating

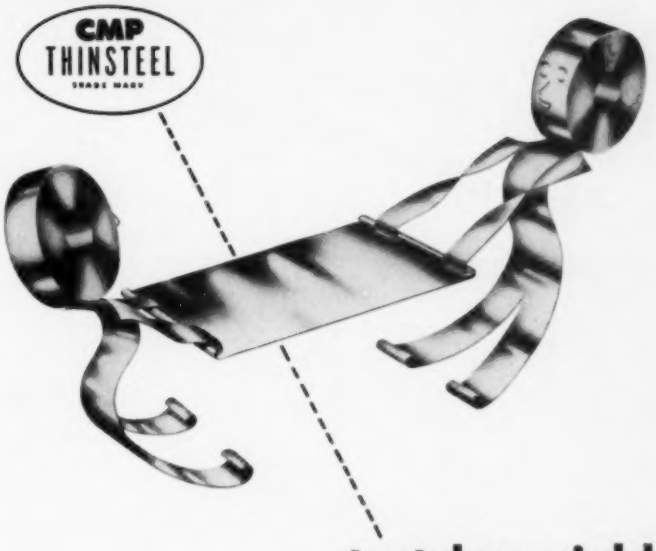
Barrett standard anhydrous ammonia is a
able in 150, 100 and 50-pound cylinders in
veniently located stock points. Send for litera
Barrett Division, Allied Chemical & Dye

70. Heat Treating

Handy, vest-pocket data book has 72 p
of charts, tables, diagrams and factual dat
late steel specifications, heat treatments,
Sunbeam Industrial Furnace Div.

for
free or controlled supply

CMP THINSTEEL TRADE MARK



stretches yield

Regardless of free or controlled supply of your light gauge cold rolled strip and/or spring steel you can always count on more feet per lb., more finished parts per ton from Thinsteel. Precision rolling and advanced processing techniques have assured greater yield for many years to users of CMP Thinsteel; provided the margin of difference (through close tolerances and exacting physicals) for improved production and product betterment.

Perhaps we can't supply your requirements now, however we welcome your interest for future needs and will be pleased to send you information.

CMP

the Cold Metal Products co.

YOUNGSTOWN 1, OHIO

New York • Chicago • Indianapolis • Detroit • St. Louis • Los Angeles • Cleveland

LOW CARBON, HIGH CARBON (Annealed or Tempered) STAINLESS AND ALLOY GRADES, ELECTRO ZINC COATED ARE AVAILABLE FROM:

THE COLD METAL PRODUCTS CO. of CALIFORNIA, 4600 McKinley Avenue, Los Angeles
Phone: PLeasant 3-1291

THE KENILWORTH STEEL CO., 750 Boulevard, Kenilworth, New Jersey
Phones: N. Y., COrtlandt 7-2427; N. J., UNionville 2-6900

PRECISION STEEL WAREHOUSE, INC., 4425 W. Kinzie, Chicago • Phone: COlumbus 1-2700

YOUR HARDNESS TESTER...

IS ONLY AS GOOD AS THE DIAMOND IT USES

Standard "C" Diamond Cone
$18.00 F. O. B. Detroit

Dependably accurate "Rockwell" testing results are obtained only when every part of your hardness testing equipment is made to precision limits. That is why a correctly designed diamond penetrator is of such great importance. Always specify CLARK Diamond Cone Penetrators, both for Standard and for Superficial "Rockwell" testing. They are accurately made to the proper size and shape; exactly formed by expert lappers. CLARK Penetrators are designed for use on all "Rockwell" type testing machines.

CLARK

TOMORROW'S ACCURACY TODAY

INSTRUMENT, INC.

10200 FORD ROAD
DEARBORN, MICH.

51. Forging

Information available on designing and construction of forging and heat treating equipment for the production of all types of armament. *Loftus Engineering Corp.*

52. Forgings

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. *Merrill Bros. Co.*

53. Furnace

New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

54. Furnace

Full information furnished on new gas-atmosphere high-production furnace for handling bright annealing of wire, strip and bar stock of copper and nonferrous copper alloys. *Holcroft & Co.*

55. Furnace, Atmosphere

Bulletin F-1 gives full description of versatile, controlled-atmosphere furnace for all steels from high carbon to high speed in range 1200 – 2800 °F. *Delaware Tool Steel Corp.*

56. Furnace Controls

Catalog N-33B describes all Rayotubes as well as Speedomax and Micromax pyrometers for economical and dependable temperature control. *Leeds & Northrup Co.*

57. Furnaces

High temperature furnaces for temperatures up to 2000 °F are described in leaflet. *Carl-Mayer Corp.*

58. Furnaces

Bulletin 346 describes new electric muffle furnaces designed to heat materials in an oxidizing atmosphere for many research, toolroom and production operations. *Harper Electric Furnace Corp.*

59. Furnaces

Illustrated literature describes newest developments in gas and electric heat treating furnaces. *Westinghouse Electric Corp.*

60. Furnaces

New bulletin 84P describes eight sizes in gas or electric models as well as conveyorized and batch or pot-type furnaces. *Despatch Oven Co.*

61. Furnaces

Complete "Buzzer" catalog available describing Buzzer high-speed gas furnaces designed primarily for heat treating high carbon and alloy steels and also atmospheric pot hardening furnaces for salt, cyanide and lead hardening. *Charles A. Hones, Inc.*

62. Furnaces, Heat Treating

Bulletin SC-132 describes both radiant tube and direct-fired roller hearth furnaces as applied to heat treatments such as annealing, clean hardening, tubing, coils, disks and sheets. Also ideal for large and small parts as in shell cases. *Surface Combustion Corp.*

63. Furnaces, Industrial

6-page folder describes 18 typical installations of gas-fired and electric furnaces of various types, complete with specially designed equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

64. Graphite Heat Exchangers

Reprint available on Graphite Heat Exchangers. Made of Karbate impervious graphite, these exchangers are used as boilers, coolers, condensers, vaporizers and absorbers in handling corrosive chemicals and can be ordered in complete size range. *National Carbon Co.*

65. Hardness Tester, Portable

Bulletin ET202 gives complete details on new Ernst portable hardness tester for direct at-the-job readings of all metal types and shapes. *Newage International, Inc.*

66. Hardness Tester, Portable

Illustrated circular describing the Ames portable hardness tester in sizes for work 1 inch to 6 inches round and flat. *Ames Precision Machine Wks.*

67. Hardness Testers

Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

68. Heat Treating

Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. *Ipsen Industries, Inc.*

69. Heat Treating

Barrett standard anhydrous ammonia is available in 150, 100 and 50-pound cylinders in conveniently located stock points. Send for literature. *Barrett Division, Allied Chemical & Dye Corp.*

70. Heat Treating

Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam Industrial Furnace Div.*

What's New

IN MANUFA

71. Heat Treating

Catalog 116 provides 72 pages of factual data on heat treating, including salt baths for carburizing, cyanide hardening, annealing or hardening stainless steel, cyclic annealing, drawing, etc. *Ajax Electric Co.*

72. Heat Treating Carriers

Complete line of standard carburizing carriers that will handle odd-shaped parts of every type through carburizing and quenching to finishing. Write for full information. *Pressed Steel Co.*

73. Heat Treating Equipment

Bulletin 820 gives detailed description with complete specifications on various size automatic quenching tanks for use with continuous heat treating equipment. *American Gas Furnace Co.*

74. Heat Treating Pots

New bulletin T-205 lists 118 patterns available in Thermalloy heat treating pots, both round and rectangular, X-rayed and pressure tested for sound and economical service. *Electro-Alloys Div.*

75. Immersion Heating

Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

76. Induction Heater

Attractive 4-page bulletin, fully illustrated, gives information and detailed specification on 20-kw. induction heater. *General Electric Co.*

77. Induction Heating

Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

78. Induction Heating

For more economical manufacture in designing and redesigning present products, send for copy of "Design and Manufacture for Profit" with full details on Tocco Induction Heating for brazing, hardening, soldering, forging or shrink-fitting. *Ohio Crankshaft Co.*

79. Induction Melting

New bulletin 14-A tells how to master melting problems with a combination of melting speed, superfine control, and over-all economy provided by the Ajax-Northrup 20-kw. converter-operated induction furnace. *Ajax Electrothermic Corp.*

80. Insulation, Block

New 4-page folder on Superex block insulation tells economical advantages and lists outstanding properties by means of conductivity and heat loss graphs and recommended thickness table. *Johns-Manville.*

81. Laboratory Safety

Newly revised edition of 40-page booklet includes recently developed data, techniques and equipment, and provides useful manual for setting up complete laboratory safety programs. *Fisher Scientific Co.*

[• If mailed from countries o amount of postage stamps n

BUSINESS RE
No Postage Stamp Necessary If Mail

4c POSTAGE WILL B

METAL PRO
7301
CL

UFACTURERS' LITERATURE

82. Laboratory Vessels
New literature available on Lecotherm combustion boats, packaged in anti-contamination capsules of ten boats each, in two styles designed especially for best resistance to slag penetration. *Laboratory Equipment Corp.*

83. Load Testing
Brochure 501 gives full details on universal testing machines in three ranges: Model TMU-A, 0-30,000, 0-6000, 0-600 lbs.; Model TMU-B, 0-15,000, 0-3000, 0-300 lbs. *National Forge & Ordnance Co.*

84. Machine Design
Fundamentals of producing low-cost machine parts—design, material and treatment—are discussed in 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

85. Magnesium Die Castings
Revealing book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co.*

86. Melting, Induction
8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

87. Metal Cleaner
New booklet tells how compound 33 performs three jobs, by removing oil, removing rust, and preparing metal for paint adhesion in one operation. *Oakite Products, Inc.*

88. Metal Coating
New bulletin describes Lithoform, an efficient protective coating which will be particularly useful to those engaged in supplying the Armed Forces with manufactured metal material. *American Chemical Paint Co.*

89. Metal Cutting
New 64-page catalog No. 28 gives prices and describes complete line of rotary files, burrs, metal-working saws and other products. *Martindale Electric Co.*

90. Metal Finishing
New check list available on sixty products and processes for metal finishing, including a new acid addition agent, a cleaning and pickling agent combined, new complete inhibitor and a new rust preventive compound. *Enthone, Inc.*

91. Metal-Forming Lubrication
New bulletin 426-B describes how colloidal graphite can solve your lubrication problems in metal-forming operations at temperatures from below zero up to 5000°F. *Acheson Colloids Corp.*

92. Metallograph
12-page catalog describes this completely new all-in-one desk-type unit for metallographic work. *American Optical Co.*

ries outside the United States, proper nps must be affixed for returning card

FIRST CLASS
PERMIT No. 1185
(Sec. 34.9 P.L. & R.)
Cleveland, Ohio

REPLY CARD
If Mailed In the United States

LL BE PAID BY—

PROGRESS
7301 Euclid Avenue
CLEVELAND 3, OHIO

HEAT-TREATING **Ipsen** EQUIPMENT

SOLVE YOUR PROCEDURE PROBLEMS...
Eliminate Pickling and Blasting Costs
...the Ipsenway

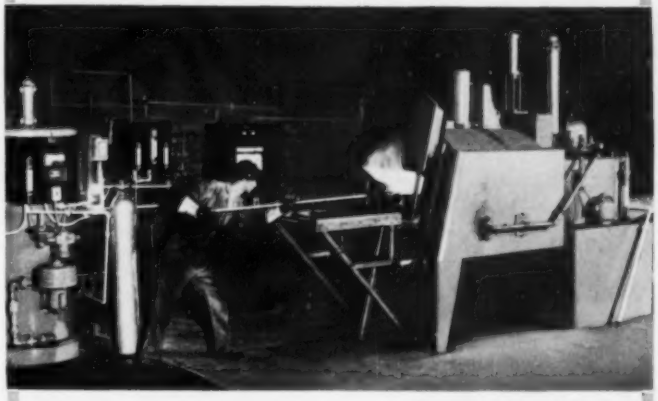


Photo of Ipsen Unit at George H. Porter Steel Treating Co., Cleveland, Ohio

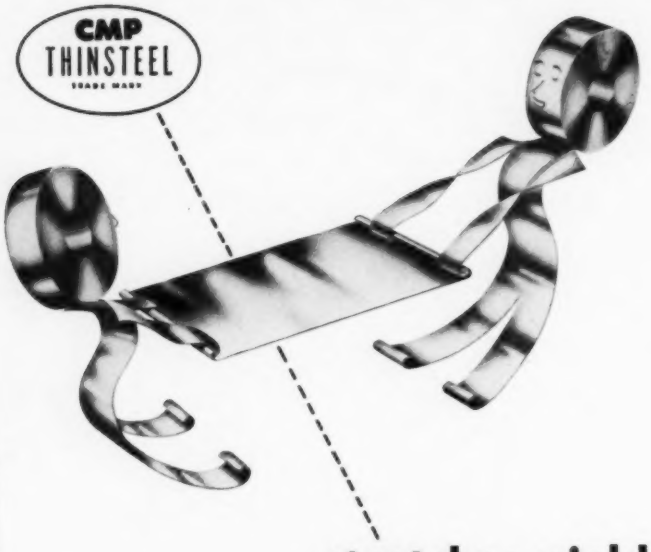
● Here is an easy way to discover how profitably Ipsen Heat-Treating Units can be applied to your jobs. Just send us samples of your work and specifications. Samples or production lots will be run in actual working units. We will establish proper procedures, record results, and supply you with time and cost figures. Then you may judge for yourself how the sealed, controlled-atmosphere principal of Ipsen Heat-Treating Units will work for you. You'll find the bright, scale-free results you get the "Ipsenway" protects against rust, reduces rejects, and eliminates pickling and blasting costs. *Write today for more facts.*

FREE Data Sheets...Write for these free data sheets covering Operating and Performance facts on actual installations.

IPSEN INDUSTRIES, INC.
PRODUCTION UNITS FOR
CARBURIZING · HARDENING · BRAZING · MARTEMPERING
715 SOUTH MAIN STREET • ROCKFORD, ILLINOIS

for
free or controlled supply

CMP THINSTEEL TRADE MARK



stretches yield

Regardless of free or controlled supply of your light gauge cold rolled strip and/or spring steel you can always count on more feet per lb., more finished parts per ton from Thinsteel. Precision rolling and advanced processing techniques have assured greater yield for many years to users of CMP Thinsteel; provided the margin of difference (through close tolerances and exacting physicals) for improved production and product betterment.

Perhaps we can't supply your requirements now, however we welcome your interest for future needs and will be pleased to send you information.

CMP

the Cold Metal Products co.

YOUNGSTOWN 1, OHIO

New York • Chicago • Indianapolis • Detroit • St. Louis • Los Angeles • Cleveland

LOW CARBON, HIGH CARBON (Annealed or Tempered) *STAINLESS AND ALLOY GRADES, ELECTRO ZINC COATED ARE AVAILABLE FROM:*

THE COLD METAL PRODUCTS CO. of CALIFORNIA, 6600 McKinley Avenue, Los Angeles
Phone: PLeasant 3-1291
THE KENILWORTH STEEL CO., 750 Boulevard, Kenilworth, New Jersey
Phones: N. Y., COrtlandt 7-2427; N. J., UNionville 2-6900
PRECISION STEEL WAREHOUSE, INC., 4423 W. Kinzie, Chicago • Phone: COlumbus 1-2790

What's New

IN MANUF

93. Metallograph

Catalog E-240 describes how new features of this research metallograph produce four different images of the same sample and permit critical work with brightfield, darkfield or polarized light, with quick, easy change-over. *Bausch & Lomb Optical Co.*

94. Metalworking Data File

Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

95. Motors and Generators

10-page illustrated bulletin 2-200 describes the extensive facilities and line of motor generators and other custom-built equipment for industry. *Electric Products Co.*

96. Oil Quenching

Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

97. Oil Quenching

Solution to difficult quench oil purification problems is discussed in new bulletin entitled "Oil Quenching" which also contains detailed operation of Honan-Crane M-10-A purifier. *Dana Corp.*

98. Oils, Cutting

For the right combination to suit your specific requirements, send for your copy of "Cutting Fluid Facts". *D. A. Stuart Oil Co.*

99. Oils, Cutting

Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service Oil Co.*

100. Photomicrography

Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

101. Plating Generators

Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

102. Polishing, Metallographic

For preparation of fine metallographic specimens, a sturdy, smooth-operating table-model metallographic polisher is described in bulletin 90. *Eberbach & Son Co.*

103. Power Bending Brakes

New catalog P51 describes complete line of power bending brakes and power universal box and pan brakes. Includes specifications and many illustrations showing wide variety of bending operations. *Dreis & Krump Mfg. Co.*

[• If mailed from countries outsi
amount of postage stamps must

METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

July, 1951

1	24	47	70	93	116
2	25	48	71	94	117
3	26	49	72	95	118
4	27	50	73	96	119
5	28	51	74	97	120
6	29	52	75	98	121
7	30	53	76	99	122
8	31	54	77	100	123
9	32	55	78	101	124
10	33	56	79	102	125
11	34	57	80	103	126
12	35	58	81	104	127
13	36	59	82	105	128
14	37	60	83	106	129
15	38	61	84	107	130
16	39	62	85	108	131
17	40	63	86	109	132
18	41	64	87	110	133
19	42	65	88	111	
20	43	66	89	112	
21	44	67	90	113	
22	45	68	91	114	
23	46	69	92	115	

Please have lit

Name

Company

Products Manu

Address

City and State

Postcard must
Studen

NUFACTURERS' LITERATURE

104. Pyrometer

Catalog No. 165 describes improved Pyro surface pyrometer. Eight instruments in one, it handles all surface and sub-surface temperature measuring jobs. *Pyrometer Instrument Co.*

105. Quenching Oil

Bulletin F-7 describes triple-action quenching oil with mineral intensifiers and anti-oxidants providing deeper hardening, less distortion and bright quenching properties in temperature up to 450°F. *Park Chemical Co.*

106. Radiography

Literature available on Allis-Chalmers Betatron for heavy-duty industrial radiography. Exposure charts showing how you can X-ray complex castings and forgings or entire assemblies with one exposure. *Picker X-Ray Corp.*

107. Reclaiming Process

Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. *Chas. Engelhard, Inc.*

108. Refractories

Bulletin 151 contains many helpful facts on Norton refractories, including bricks, burner blocks, cores and muffles. *Norton Co.*

109. Refractories

40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. *Carborundum Co.*

110. Salt Baths

Technical data sheets now available on two new carburizing compounds, barium-base materials for use in liquid bath carburizing. One is a briquetted mixture, relatively high in sodium cyanide and used to control cyanide concentration in operating baths. The other is a granular mixture used for the original fusion and to replace drag-out losses. *American Cyanamid Co.*

111. Solder

36-page educational brochure on the properties and applications of solder. Profusely illustrated, with a resume of technical data and solder specifications of ASTM, SAE, Federal and Military agencies. *American Smelting & Refining Co.*

112. Specimen Polishing with Diamond Compound

4-page folder describes the advantages of diamond abrasives for polishing metallurgical specimens. Diamet-Hyprez is offered in three different particle sizes, all in 5-gram and 18-gram gun applicators. *Buehler, Ltd.*

113. Stainless Steel Hardening

16-page illustrated booklet giving test results and showing advantages and applications of stainless steel parts hardened by the Scottsonizing process. *C. U. Scott & Son, Inc.*

utside the United States, proper must be affixed for returning card

ve literature circled at the left sent to me.

Title

Manufactured

State

must be mailed prior to October 1, 1951— Students should write direct to manufacturers.

114. Steel, Brake Die

For full information on top quality brake die steel, engineered to machine easily and give long service, write for folder 560. *Bethlehem Steel Co.*

115. Steel, Forging

Technical bulletin 31 furnishes helpful information on stainless forging problems and includes specific data on chemical composition of alloy steels. *Timken Roller Bearing Co.*

116. Steels, Alloy

Booklet on Carilloy steels tells how No. 4150 and others provide toughness, strength, and lightweight durability under trying conditions of service. *U. S. Steel Co.*

117. Steels, Alloy

New book is now available on the selection of the proper alloy steel grades for each manufacturer's needs. Write for free copy of "Wheelock, Lovejoy Data Book". *Wheelock, Lovejoy & Co.*

118. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. *Inland Steel Co.*

119. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

120. Testing Machine

Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. *Tinius Olsen Testing Machine Co.*

121. Tool & Lab Furnace

New literature on hardening and tempering furnace designed to give automatic control of the entire temperature range from 300 to 2000°F. *K. H. Huppert Co.*

122. Tool Steel

Selector is handy chart featuring general and heat treating data on non-deforming, water hardening, shock-resistant, hot work and high speed tool steels and hollow die steels. *A. Milne & Co.*

123. Tool Steels

Information on Warplis products, stock size and price folders will be sent on request, along with name of nearest distributor. *Pittsburgh Tool Steel Wire Co.*

124. Tubes, Bars, Steel

New stock list now available on 52100 tubing and bars as well as ring forgings. *Peterson Steels, Inc.*

125. Vacuum Pumps

New 6-page booklet gives complete directions for setting up and operating Type VSD high vacuum pumps, along with illustrated listing of repair parts. *Kinney Mfg. Co.*

126. Vapor Degreasing

Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

127. Welding

New booklet, "Welding with Multiple Electrodes in Series—A New Method of Unionmelt Welding", explains the series-arc technique of submerged melt welding where depth of penetration of weld metal into base metal can be controlled. Also used in cladding of stainless steels, hard-facing rods, and nonferrous cladding and surfacing applications. *Linde Air Products Co.*

128. Welding Electrodes

"Arc Welding Stainless Steel Without Columbium", title of a new booklet giving complete details on Arcaloy 308 ELC and 316 ELC for welding stainless types 321 and 316 without appreciable carbide precipitation. *Alloy Rods Co.*

129. Welding Stainless Steels

For all users of welded stainless steel equipment, a detailed account of the properties of extra-low-carbon stainless steel is provided in technical paper, "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content". *Electro Metallurgical Co.*

130. Welding Stainless Steels

"The Welding of Stainless Steels", a new 48-page handbook, describes all phases of stainless steel arc welding. It discusses and illustrates the metallurgical background, specific uses of alloying elements and facts in general pertaining to welding of stainless steels. *McKay Co.*

131. Wire Cloth, Brass and Copper

Free booklet lists mesh, diameter of wire, per cent of open area, weight and other important data on industrial wire cloth in brass and copper. *Chase Brass & Copper Co.*

132. Wrought Alloys

New price list available on Haynes wrought alloys, including information on electrostatic precipitators for removing corrosive liquids and alloy C electrodes for installations where mixed acids are present. *Haynes Stellite Co.*

133. X-Ray Diffraction

Bulletin 304 describes the Hilger X-ray diffraction unit for determining internal strain or distortion, types of alloy formation, grain sizes and effect of heat treatment to establish correct annealing technique. *Jarrell-Ash Co.*

IOUS GRAPHITE

L PURPOSES!

t conductivity rate of the practical esistant materials.

tant to corrosion by alis, hot or cold.

om corrosion scale.

d to metals.

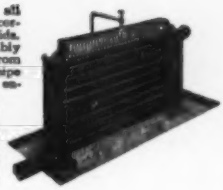
thermal shock.

ation of product.

easy to install and maintain.

Style FH heat exchangers (Size 1½): **Are especially recommended for tanks with solution depths of 16 inches or less. Write for catalog section S-6750.**

coolers: For all jobs involving corgases and liquids. to cooler assembly made quickly from ard items in 5 pipe apacity easily enor reduced by or subtracting rd sections. t construction plant room. No l supporting re needed. Write talog section



Concentric Tube exchangers: **Available in two types. Series 10A is small, low-priced, gives true counterflow. Exceptionally good for small flow rates at narrow temperature differences . . . Series 20A manufactured with "Karbate" inner and outer piping, and is used to transfer heat between two corrosive fluids. Both have sectional construction, can be added to or subtracted from at will. Sturdy, can be moved from place to place after assembly, adapted to any method of mounting on floor, wall, or ceiling. Write for catalog section S-6670.**

ne of "Karbate" impervious aphite pipe and fittings

rrosive chemicals includes: "Karbate" pumps ign embodying impervious graphite case, otary seal which eliminates the stuffing box. uced up to 33%. Write for catalog section information, S-7200 for pump information.

What's New

IN MANUFACTURERS' LITERATURE

93. Metallograph

Catalog E-240 describes how new features of this research metallograph produce four different images of the same sample and permit critical work with brightfield, darkfield or polarized light, with quick, easy change-over. *Bausch & Lomb Optical Co.*

94. Metalworking Data File

Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

95. Motors and Generators

10-page illustrated bulletin 2-200 describes the extensive facilities and line of motor generators and other custom-built equipment for industry. *Electric Products Co.*

96. Oil Quenching

Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

97. Oil Quenching

Solution to difficult quench oil purification problems is discussed in new bulletin entitled "Oil Quenching" which also contains detailed operation of Honan-Crane M-10-A purifier. *Dana Corp.*

98. Oils, Cutting

For the right combination to suit your specific requirements, send for your copy of "Cutting Fluid Facts". *D. A. Stuart Oil Co.*

99. Oils, Cutting

Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service Oil Co.*

100. Photomicrography

Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

101. Plating Generators

Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

102. Polishing, Metallographic

For preparation of fine metallographic specimens, a sturdy, smooth-operating table-model metallographic polisher is described in bulletin 90. *Eberbach & Son Co.*

103. Power Bending Brakes

New catalog P51 describes complete line of power bending brakes and power universal box and pan brakes. Includes specifications and many illustrations showing wide variety of bending operations. *Dreis & Krump Mfg. Co.*

104. Pyrometer

Catalog No. 165 describes improved Pyro surface pyrometer. Eight instruments in one, it handles all surface and sub-surface temperature measuring jobs. *Pyrometer Instrument Co.*

105. Quenching Oil

Bulletin F-7 describes triple-action quenching oil with mineral intensifiers and anti-oxidants providing deeper hardening, less distortion and bright quenching properties in temperature up to 450 °F. *Park Chemical Co.*

106. Radiography

Literature available on Allis-Chalmers Betatron for heavy-duty industrial radiography. Exposure charts showing how you can X-ray complex castings and forgings or entire assemblies with one exposure. *Picker X-Ray Corp.*

107. Reclaiming Process

Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. *Chas. Engelhard, Inc.*

108. Refractories

Bulletin 151 contains many helpful facts on Norton refractories, including bricks, burner blocks, cores and muffles. *Norton Co.*

109. Refractories

40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. *Carborundum Co.*

110. Salt Baths

Technical data sheets now available on two new carburizing compounds, barium-base materials for use in liquid bath carburizing. One is a briquetted mixture, relatively high in sodium cyanide and used to control cyanide concentration in operating baths. The other is a granular mixture used for the original fusion and to replace drag-out losses. *American Cyanamid Co.*

111. Solder

36-page educational brochure on the properties and applications of solder. Profusely illustrated, with a resume of technical data and solder specifications of ASTM, SAE, Federal and Military agencies. *American Smelting & Refining Co.*

112. Specimen Polishing with Diamond Compound

4-page folder describes the advantages of diamond abrasives for polishing metallurgical specimens. Diamet-Hyprez is offered in three different particle sizes, all in 5-gram and 18-gram gun applicators. *Buehler, Ltd.*

113. Stainless Steel Hardening

16-page illustrated booklet giving test results and showing advantages and applications of stainless steel parts hardened by the Scottsonizing process. *C. U. Scott & Son, Inc.*

114. Steel, Brake Die

For full information on top quality brake die steel, engineered to machine easily and give long service, write for folder 560. *Bethlehem Steel Co.*

115. Steel, Forging

Technical bulletin 31 furnishes helpful information on stainless forging problems and includes specific data on chemical composition of alloy steels. *Timken Roller Bearing Co.*

116. Steels, Alloy

Booklet on Carilloy steels tells how No. 4150 and others provide toughness, strength, and lightweight durability under trying conditions of service. *U. S. Steel Co.*

117. Steels, Alloy

New book is now available on the selection of the proper alloy steel grades for each manufacturer's needs. Write for free copy of "Wheelock, Lovejoy Data Book". *Wheelock, Lovejoy & Co.*

118. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. *Inland Steel Co.*

119. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

120. Testing Machine

Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. *Tinius Olsen Testing Machine Co.*

121. Tool & Lab Furnace

New literature on hardening and tempering furnace designed to give automatic control of the entire temperature range from 300 to 2000 °F. *K. H. Huppert Co.*

122. Tool Steel

Selector is handy chart featuring general and heat treating data on non-deforming, water hardening, shock-resistant, hot work and high speed tool steels and hollow die steels. *A. Milne & Co.*

123. Tool Steels

Information on Warplis products, stock size and price folders will be sent on request, along with name of nearest distributor. *Pittsburgh Tool Steel Wire Co.*

124. Tubes, Bars, Steel

New stock list now available on 52100 tubing and bars as well as ring forgings. *Peterson Steels, Inc.*

125. Vacuum Pumps

New 6-page booklet gives complete directions for setting up and operating Type VSD high vacuum pumps, along with illustrated listing of repair parts. *Kinney Mfg. Co.*

126. Vapor Degreasing

Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

127. Welding

New booklet, "Welding with Multiple Electrodes in Series—A New Method of Unionmelt Welding", explains the series-arc technique of submerged melt welding where depth of penetration of weld metal into base metal can be controlled. Also used in cladding of stainless steels, hard-facing rods, and nonferrous cladding and surfacing applications. *Linde Air Products Co.*

128. Welding Electrodes

"Arc Welding Stainless Steel Without Columbium", title of a new booklet giving complete details on Arcaloy 308 ELC and 316 ELC for welding stainless types 321 and 316 without appreciable carbide precipitation. *Alloy Rods Co.*

129. Welding Stainless Steels

For all users of welded stainless steel equipment, a detailed account of the properties of extra-low-carbon stainless steel is provided in technical paper, "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content". *Electro Metallurgical Co.*

130. Welding Stainless Steels

"The Welding of Stainless Steels", a new 48-page handbook, describes all phases of stainless steel arc welding. It discusses and illustrates the metallurgical background, specific uses of alloying elements and facts in general pertaining to welding of stainless steels. *McKay Co.*

131. Wire Cloth, Brass and Copper

Free booklet lists mesh, diameter of wire, per cent of open area, weight and other important data on industrial wire cloth in brass and copper. *Chase Brass & Copper Co.*

132. Wrought Alloys

New price list available on Haynes wrought alloys, including information on electrostatic precipitators for removing corrosive liquids and alloy C electrodes for installations where mixed acids are present. *Haynes Stellite Co.*

133. X-Ray Diffraction

Bulletin 304 describes the Hilger X-ray diffraction unit for determining internal strain or distortion, types of alloy formation, grain sizes and effect of heat treatment to establish correct annealing technique. *Jarrell-Ash Co.*

[• If mailed from countries outside the United States, proper amount of postage stamps must be affixed for returning card]

METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

July, 1951

1	24	47	70	93	116
2	25	48	71	94	117
3	26	49	72	95	118
4	27	50	73	96	119
5	28	51	74	97	120
6	29	52	75	98	121
7	30	53	76	99	122
8	31	54	77	100	123
9	32	55	78	101	124
10	33	56	79	102	125
11	34	57	80	103	126
12	35	58	81	104	127
13	36	59	82	105	128
14	37	60	83	106	129
15	38	61	84	107	130
16	39	62	85	108	131
17	40	63	86	109	132
18	41	64	87	110	133
19	42	65	88	111	
20	43	66	89	112	
21	44	67	90	113	
22	45	68	91	114	
23	46	69	92	115	

Please have literature circled at the left sent to me.

Name _____ Title _____

Company _____

Products Manufactured _____

Address _____

City and State _____

Postcard must be mailed prior to October 1, 1951—
Students should write direct to manufacturers.

"KARBATE" BRAND IMPERVIOUS GRAPHITE HEAT EXCHANGERS *FOR ALL PURPOSES!*

The "Karbate" impervious graphite heat exchangers illustrated are used extensively as boilers, coolers, condensers, vaporizers, evaporators, heaters and absorbers in handling corrosive chemicals, either hot or cold. They *all* can be had in a complete size range. *All of them* offer the following advantages:

- **Highest heat conductivity rate of the practical corrosion-resistant materials.**
- **Highly resistant to corrosion by acids or alkalis, hot or cold.**
- **Freedom from corrosion scale, as compared to metals.**
- **Immune to thermal shock.**
- **No contamination of product.**
- **Strong and easy to install and maintain.**

Shell-and-Tube: Series 70A—Two sizes, 16.4 sq. ft., and 24.6 sq. ft. of outside surface area respectively. Tubes easily replaced in the field. Interchangeable single and double-pass construction.

Series 240A—70.6 feet of outside heat transfer surface. Easy tube replacement. Easily converted on job to single, double, or four-pass tube side flow by simple change of fixed covers. Steel, shell, over-size shell connections, impingement plates and drain and vent plugs integral with shell end castings. Stainless-steel baffles assembled with steel tie rods to form protective cage for tube bundle. Removable "Karbate" tube bundle. Write for catalog sections for S-6690, S-6715 for details of applications, maintenance, sizes and characteristics of these exchangers.

Style FH heat exchangers (Size 1½): Are especially recommended for tanks with solution depths of 16 inches or less. Write for catalog section S-6750.

Cascade coolers: For all cooling jobs involving corrosive gases and liquids. Complete cooler assembly may be made quickly from 4 standard items in 5 pipe sizes. Capacity easily enlarged or reduced by adding or subtracting standard sections. Compact construction to save plant room. No special supporting structure needed. Write for catalog section S-6780.

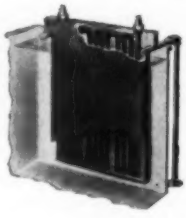


Plate heaters: Used to heat or cool corrosive liquids in tanks and vessels. Compact, completely assembled, easy to put in. Used in pickling, etching, plating and cleaning tanks. Complete size range. Models for horizontal and vertical mounting. Write for catalog section S-6620.

Concentric Tube exchangers: Available in two types. Series 10A is small, low-priced, gives true counterflow. Exceptionally good for small flow rates at narrow temperature differences . . . Series 20A manufactured with "Karbate" inner and outer piping, and is used to transfer heat between two corrosive fluids. Both have sectional construction, can be added to or subtracted from at will. Sturdy, can be moved from place to place after assembly, adapted to any method of mounting on floor, wall, or ceiling. Write for catalog section S-6670.

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

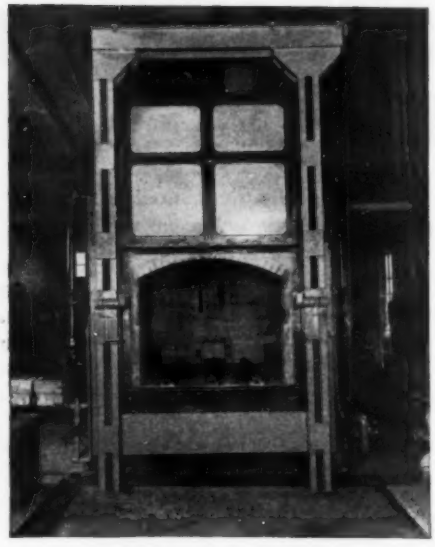
In Canada: National Carbon Limited
Montreal, Toronto, Winnipeg

A full line of "Karbate" impervious graphite pipe and fittings

for conveying corrosive chemicals includes: "Karbate" pumps of advanced design embodying impervious graphite case, impeller, and a rotary seal which eliminates the stuffing box. Pump prices reduced up to 33%. Write for catalog section S-7000 for pipe information, S-7200 for pump information.

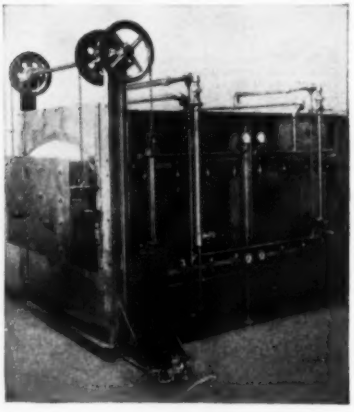
DREVER

The hearth and side tile of this furnace, built by the Drever Company of Philadelphia, Pa., are made of CARBOFRAX silicon carbide tile. This is a single-end, under-fired furnace used for annealing, forming and general-purpose heat treating.



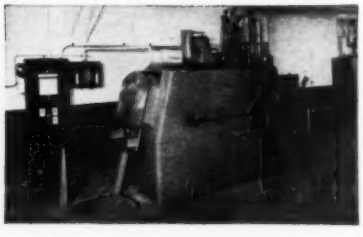
AMERICAN GAS

This gas-fired oven furnace is built by the American Gas Furnace Company of Elizabeth, N. J. It is designed to operate at temperatures up to 1800°F, for box carburizing, annealing large forgings, etc. The hearth, 42 inches wide by 85 inches long, is constructed of CARBOFRAX tile and is carried on CARBOFRAX supports.



In almost all heat-treating furnaces there are places where Super Refractories pay

IPSEN



This furnace contains a complete CARBOFRAX muffle. It is a gas-fired unit built by Ipsen Industries, Inc., of Rockford, Illinois, and is designed especially for bright annealing, hardening, carburizing and stress relieving.

For hearths and muffles where heat must travel *through* a refractory—for floors which must resist abrasion at high temperatures—for supports which must keep the floor flat and level under heavy loads—for burner ports and all other furnace parts subject to flame erosion, cracking or spalling — Super Refractories by CARBORUNDUM will pay their way, usually many times over.

A 40-page booklet, "Super Refractories for heat treatment furnaces," gives recommendations for many specific types of furnaces. A copy is yours for the asking.

THE CARBORUNDUM COMPANY

Dept. C-71, Refractories Div. • **Perth Amboy, New Jersey**

"Carbofrax" and "Carborundum" are registered trademarks which indicate manufacture by The Carborundum Company.

How to get the most from your high temperature tubes: Ask the experts!

CHANCES are you can find several high temperature steels that will solve your heat, pressure, corrosion and oxidation problems. But there's only *one* steel that will give you maximum tube life per dollar —the best life/cost ratio.

The Timken Company metallurgists—the recognized authorities on high temperature steels—can help you find that one steel. With a background of 20 years of steel development and with 23 different analyses at their disposal—plus wide field experience—they are qualified to help you choose the correct analysis for your application. And whatever analysis is recommended, you can be sure of uniform quality because the Timken Company carefully controls quality from melt shop through final inspection.

Our "RSQ"—Research, Supply, Quality —can solve your tube problems. *Ask the experts!* The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

The Timken Company pioneered in testing high temperature steels. Hot twist apparatus shown here is used to evaluate the hot working characteristics of high temperature steels.

This month's report is on: **4-6% CR.-MO.**

Suggested for applications where high creep resistance is not required, but where good stability, corrosion and oxidation resistance are essential. For cracking furnace tubes, heat exchangers, super-heaters, air heating equipment and forgings and other parts exposed to oxidation or oil corrosion.

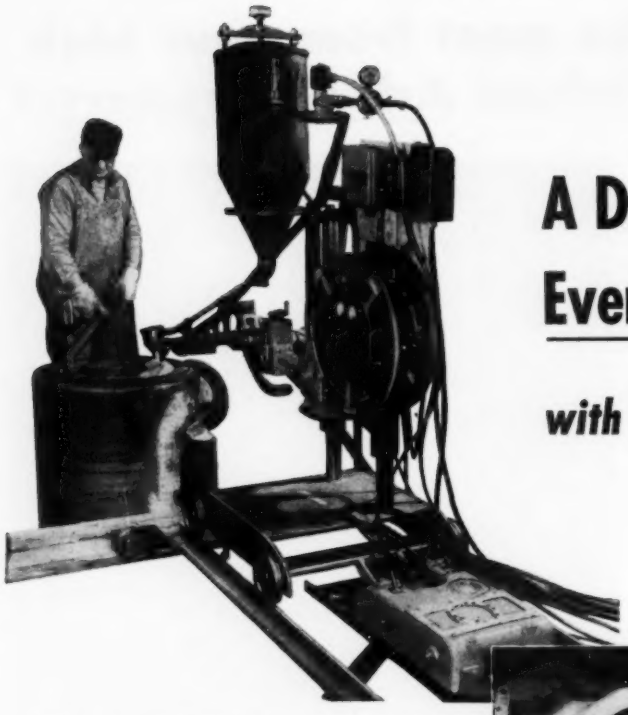
23 TIMKEN STEELS FOR HIGH TEMPERATURE SERVICE

Carbon	Sicromo 2	Sicromo 5S	16-13-3
Carbon-Mo.	Sicromo 2½	Sicromo 5MS	25-20
DM-2	2¼% Cr.-1% Mo.	Sicromo 7	25-12
Silmo	Sicromo 3	Sicromo 9M	35-15*
DM	4-6% Cr.-Mo.	18-8 Stainless	16-25-6*
2% Cr.-Mo.	4-6% Cr.-Mo.-Ti.	18-8 Cb	

**Not available as seamless tubing at the present time.*

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

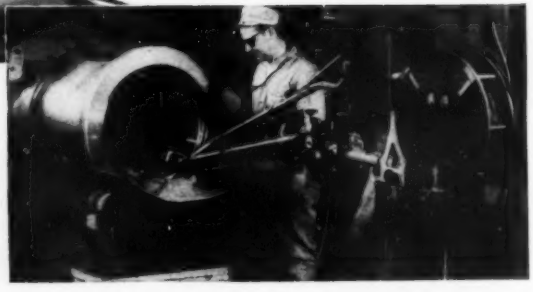
Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing



A Day's Output Every Hour

with UNIONMELT Welding

Trade-Mark



(*Above*) UNIONMELT welding a chromium alloy end ring to a mild steel pump shell takes only 1 hour and 23 minutes. Former methods of welding took 10 hours. Ring and shell, each 4 in. thick, are joined in consecutive passes as the work rotates under the UNIONMELT welding head.

(*Right*) This UNIONMELT welding machine smoothly deposits a sound, corrosion-resistant overlay inside a mild steel pump shell. Stainless steel metal — 20 to 120 lb. of it, depending on pump size — builds up at 20 lb. per hour. Highest former rate was 2 lb. per hour.

In making high-pressure steam pumps, these two welding operations used to take 20 hours—2½ working days. This was cut to 2½ hours by UNIONMELT welding as shown above. In addition, finishing costs dropped sharply because the UNIONMELT deposits are smoother and need less machining.

High-speed production is common wherever automatic UNIONMELT welding is used to join ferrous or non-ferrous metals. Welds up to 3 in. thick can be made in one pass; light-gage sheet can be welded at speeds up to 200 in. per minute.

UNIONMELT welding is only one of many time- and moneysaving LINDE methods for making, cutting, joining, treating, and forming metals. So, whatever you do with metals, there is a good chance that LINDE know-how, show-how, and equipment can help you do it better, more quickly, or at lower cost. Telephone or write to our nearest office today. LINDE AIR PRODUCTS COMPANY, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in Other Principal Cities. In Canada: Dominion Oxygen Company, Limited, Toronto.

Unionmelt

Trade-Mark

EQUIPMENT AND SUPPLIES
for fast, automatic electric welding.
No sparks, spatter, smoke, or flash.

The terms "Linde" and "Unionmelt" are registered trade-marks of Union Carbide and Carbon Corporation.

Check the advantages of melting and remelting quality steel with TOCCO Induction Heating

Several TOCCO melting furnaces may be operated from one TOCCO high-frequency power source.

- √ Extremely Rapid Melting
- √ High Efficiency on Intermittent Operation
- √ Good Mixing because of Natural Agitation
- √ Extremely Low Alloy Loss
- √ High Reproducibility of Results
- √ No Carbon Pick-up
- √ No Contamination when Composition of Charges is Changed
- √ Minimum Space Requirements
- √ No Special Installation Charge
- √ Simple, Safe Operation
- √ Clean, Comfortable Working Conditions

If any of these advantages suggest economies in your operations write us for full details—no obligation, of course.

Some Users of TOCCO High-Frequency Melting Furnaces

American Electro Metal Corp.
Haynes Stellite Company
E. I. Dupont de Nemours & Co.
Union Carbide and Carbon Corporation
Allis-Chalmers Mfg. Co.
Watertown Arsenal
Wright Aeronautical Corporation
Watervliet Arsenal
Arwood Precision Casting Co.
Various Atomic Energy Plants and Laboratories

THE OHIO CRANKSHAFT COMPANY
CLEVELAND 1, OHIO

TOCCO

Hardening • Brazing
Annealing • Soldering
Forging • Melting

OLSEN SUPER "L"

CHOSEN by ANOTHER LEADING STEEL MILL

Steel mills, Government laboratories, automobile plants, foundries, technical schools and colleges, airplane plants, machinery builders, independent testing laboratories, plastics producers—these are but a few of the wide variety of industries where the low-cost, versatility, accuracy, and operating convenience of the new Olsen Super "L" Testing Machine are paying off.

By choosing the Olsen Super "L" you obtain the only testing machine available at any price which gives you a 50 to 1 ratio of test ranges; SelecΦrange indicating system to change ranges under test at the flip of a switch; automatic fool-proof range indicating system; easy-to-read 28" dial with all 3 ranges color indicated; and simplified controls. If your budget is lean—the Super "L" puts quality standard tension, compression and flexure testing well within the range of your pocketbook. If money is no particular problem, the Super "L" still offers the best buy in testing machines on the market today—feature for feature.

WRITE TODAY FOR BULLETIN 40

TINIUS Φ OLSEN

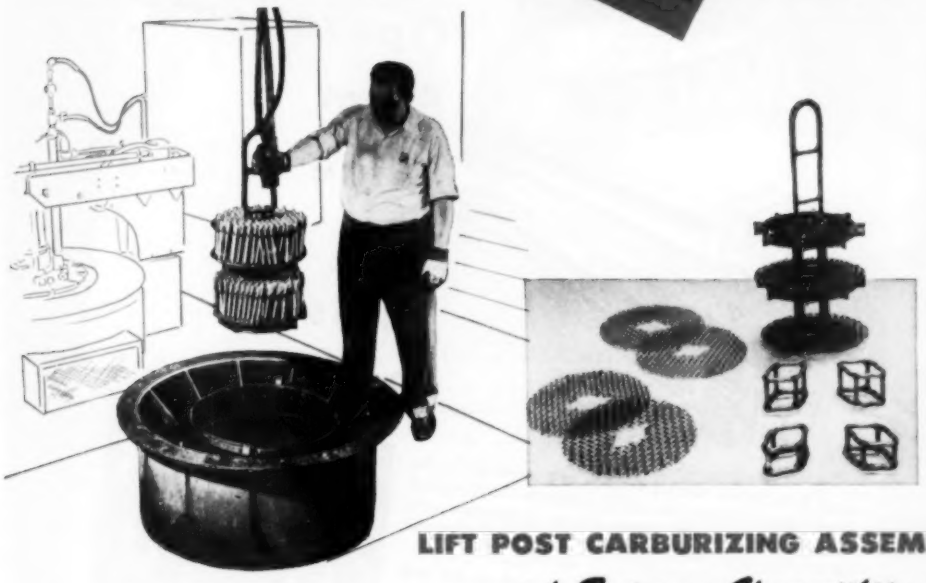
Testing & Balancing Machines

TINIUS OLSEN
TESTING MACHINE CO.
2030 Easton Rd., Willow Grove, Pa.

ROLOCK

FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT



LIFT POST CARBURIZING ASSEMBLY

of Extreme Versatility

The Carburizing Assembly shown above was fabricated from Inconel by Rolock for Union Special Machine Co., Chicago . . . whose Industrial Sewing Machines are used throughout the world.

It consists of a lift post and bottom grid, to which may be added, at desired levels, a series of spacers, supporting grids and wire cloth screens of varied mesh sizes thru which steel shafts are vertically inserted for heat treatment, followed by direct oil quench in a flush tank, capacity 800 gallons continuous flow per minute.

Photo shows load of 200 lbs. in 54 lb. fixture (ratio almost 4 to 1) carburized at 1650° F. (.030 Case). The completely open structure permits uniform quench, no shielding, minimum warping (straight within .010"). Rolock designs, fabricates and welds all types of heat treating and finishing equipment for your specific needs . . . for better work, longer service life, lowest hour costs. Send us your problems . . . we'll give you sound solutions.

Offices in: PHILADELPHIA • CLEVELAND • DETROIT • HOUSTON • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES • MINNEAPOLIS

ROLOCK INC. • 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

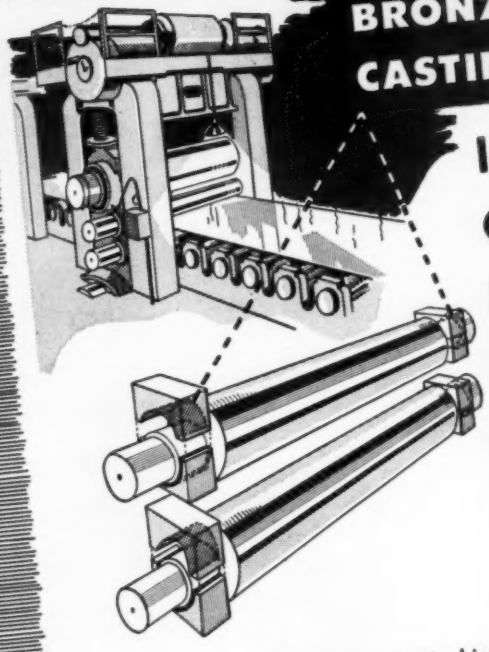
JOB-ENGINEERED for better work
Easier Operation, Lower Cost

4RL51

THE METAL INDUSTRY REQUIRES

BRONZE CASTINGS

In All Operations From Mine to Finished Product



Cast Bronze roll neck bearings are required in the production of wrought metal products. Cast bronze withstands best the tremendous pressures and relatively high temperatures to which roll neck bearings are subjected.

Bronze is unique because it is used as an end product as well as a necessary tool in the production of other metal goods.

Mining equipment . . . milling equipment . . . fabricating equipment . . . rely upon cast bronze bushings, bearings, valves, etc., in the efficient production of metals from Mine to Finished Product.

Cast Bronze meets the requirements of both industry and consumer.

Specify—LAVIN NON-FERROUS INGOT—*Quality*

R. LAVIN & SONS, INC.

Refiners of Brass, Bronze and Aluminum

3426 SOUTH KEDZIE AVENUE · CHICAGO 23, ILLINOIS

REPRESENTATIVES IN PRINCIPAL CITIES

The use of N-A-X ALLOY STEEL *in Aircraft Gas Turbines saves up to 50 per cent of critical Stainless Steel.*

Conservation is possible – without sacrifice with use of N-A-X ALLOY STEELS

With the demand for greatly increased quantities of the critical and strategic Stainless Steels used in Jet Engines intensified by the acceleration of the building program, the Air Force requested the producers of these engines to seek *suitable* material with less critical alloy content to replace the Stainless Steel for certain moderate temperature application in these aircraft gas turbines.

The steel selected had to be of low-alloy content with high strength and good welding characteristics. Ordinary low carbon steel did not meet the requirements because of its low tensile properties and the fact that it could not be satisfactorily welded by the inert arc process, which is widely used in aircraft gas turbine manufacture.

The data available from tests made on several weldable low-alloy, high-strength steels indicated that N-A-X ALLOY STEEL was the most satisfactory of the group — *its selection followed.* Unlike other possible substitutes, N-A-X ALLOY STEEL has good low temperature impact values, maintains its higher strength and is not subject to temper brittleness in the wide operating temperature range required of the steel for this purpose — from a low of −70°F. to +800°F.

The use of N-A-X ALLOY STEEL for this application has cut the amount of Stainless Steel required in half. This is of considerable importance to the Air Force.

GREAT LAKES STEEL CORPORATION

N-A-X Alloy Division — Ecorse, Detroit 29, Michigan

NATIONAL STEEL CORPORATION

MARKS THE SPOT

RELATIVE WORKABILITY of Carpenter STAINLESS STEELS
STANDARD ANALYSIS TABLE
OPERATION
THE CARPENTER STEEL COMPANY READING, PA.

Where *Carpenter* Helps You in Your Work with Stainless

Getting better machined finishes, longer tool life and fewer rejects on Stainless jobs is the answer to—

- **increased production from every shift**
- **more parts from every pound of material**

To make Stainless Steel do its best for you, take advantage of the help Carpenter can provide. We'll be glad to give you personal help in the shop and useful printed information that makes it easier to work with Stainless.

The new Carpenter Stainless Slide Chart quickly gives you information your men need to know. It gives the relative workability for many grades, useful information for jobs where you do *blanking, deep drawing, forging, heading, machining, welding,* etc. You will also find a complete table of information on the physicals for the Stainless grades. Just drop us a note, on your company letterhead indicating your title, and we will put your Carpenter Stainless Slide Chart in the mail for you.

The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Department: The Carpenter Steel Company, Reading, Pa., "CARSTEELCO"

DON'T WAIT... COOPERATE! The U.S. Needs Your Steel Scrap, Now

Carpenter STAINLESS STEEL
takes the problems out of production

For Help on Stainless Jobs Call Carpenter. Warehouses in principal cities throughout the country.

ALL TINNERMAN Speed Nuts®

are heat treated in

NICHROME* MUFFLES

Cast and fabricated Nichrome muffle, of the type used in all Tinnerman's reciprocating controlled-atmosphere ("shaker hearth") furnaces. Weight: approximately 1,400 lbs.

Such muffles have served as long as 12,000 hours without requiring attention—at temperatures in excess of 1700°F.

Every shaker hearth furnace used in heat treating the Tinnerman "SPEED NUT" brand of fasteners—universally used in a host of applications—is equipped with a Nichrome muffle!

In the all-important heat treating phase of manufacture at Tinnerman, the reliance placed upon Nichrome muffles is best expressed in the words of Mr. S. J. Andrews, Works Manager: "Nichrome muffles," he says, "stand up under intense heat and give maximum service."

Whatever *your* heat treating requirements, consult with us. For over 30 years, we have been engineering and casting heat-resisting nickel-chrome-alloys—helping manufacturers to *reduce heat-hour costs* with equipment unexcelled for efficiency, economical service, and long life. Although the present emergency is making unprecedented demands upon the resources of Driver-Harris Company, we shall be glad to make recommendations based upon your specific needs, and serve you to the best of our ability.

Battery of reciprocating, controlled atmosphere furnaces at the new Cleveland, Ohio plant of Tinnerman Products, Inc. (A) Charge ends; (B) Discharge ends.

Furnaces manufactured by American Gas Furnace Company, Elizabeth, N. J.

Nichrome* *is manufactured only by*

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T. M. Reg. U. S. Pat. Off.

Are You Ordering Higher Alloy Grades Than Necessary for Your Defense Orders?

Many of the high-priority defense orders now being submitted by manufacturers of essential equipment call for steels considerably richer in alloy content than is necessary.

Such practice is wasteful. It wastes nickel, molybdenum and other alloying elements that are in short supply throughout the nation.

Here is an example. Bethlehem recently received an approved order for 4340 nickel-chromium-molybdenum steel, aircraft-quality, in a small size presumably for aircraft-engine parts. After Bethlehem metallurgists looked into the situation it developed that this steel was actually intended for making brackets that hold together the crates in which aircraft engines are shipped. It was obvious that ordinary carbon steel would serve the purpose, and our metallurgists recommended the use of 1045 grade, which was finally accepted.

Generally speaking, unless special properties such as heat-resistance or corrosion-resistance are required, there is no advantage in using steels with more alloy content than the minimum needed to make the piece quench out properly. Over-alloying will only serve to increase the sensitivity of the steel to quenching cracks. If you have any questions, particularly on conservation of the alloy steels needed for defense purposes, call or write for metallurgical advice.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL

Nothing takes the place of Chromel Alumel thermocouples

When you're working with heat between 1000° and 2000° F. and accurate temperature measurement is essential to the results you want to produce, you'll find there is no suitable substitute for Hoskins CHROMEL-ALUMEL thermocouple alloys. They're unconditionally guaranteed to register true temperature—E.M.F. values within very close specified limits. Exceptionally durable . . . so resistant to oxidation that you need not pack the protection tube. Hence, highly responsive to temperature fluctuations. And, in spite of hard use, they maintain their fine degree of accuracy over far longer periods of time than any other known base metal thermocouple materials.

So for positive long-life assurance of accurate temperature measurement, insist that your pyrometers be calibrated for CHROMEL-ALUMEL thermocouples. And important, too . . . be sure you use CHROMEL-ALUMEL *extension* leads instead of so-called "compensating" wires. For, when the couple and the lead are of identical alloy compositions there is no possibility of "cold-end" errors. Our Catalog 59-R contains a complete technical explanation . . . want a copy?

CHROMEL-ALUMEL couples and leads are available through your instrument manufacturer or pyrometer service company . . . ask for them by name!

HOSKINS MANUFACTURING COMPANY

4445 LAWTON AVE. • DETROIT 8, MICHIGAN

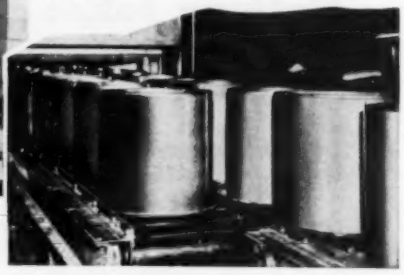
NEW YORK • CLEVELAND • CHICAGO

West Coast Representatives in Seattle, San Francisco, Los Angeles
In Canada: Walker Metal Products, Ltd., Walkerville, Ontario

**the* [illegible] nickel-chromium resistance alloy that first made electrical heating practical*

◀ A battery of Inconel conveyor rolls in a brass strip annealing furnace, Scovill Mfg. Co., Waterbury, Conn. The furnace was fabricated by SURFACE COMBUSTION CORP., Toledo, Ohio.

Input end of brass annealing furnace showing coiled brass strip resting on Inconel furnace pans at Scovill Mfg. Co., Waterbury, Conn. These circular pans were fabricated by THE PRESSED STEEL CO., Wilkes-Barre, Pa. ▼



MODERN furnace equipment in one of world's most *MODERN* brass mills

Completed in 1949, the new Continuous Strip Mill of Scovill Manufacturing Co., at Waterbury, Conn., is rated as one of the most modern completely integrated brass mills in the world. From the giant continuous slab-casting machinery at one end, to the tractor loaders a quarter of a mile away at the other – every unit operation has been mechanized to the highest degree.

In planning the mill, considerable thought was given to minimizing future maintenance costs. Scovill knew that one source of serious upkeep could be annealing furnace equipment.

So, on the advice of Surface Combustion Corp., and The Pressed Steel Co., annealing furnace pans were made of a metal with a proved record of long life in high-temperature applications . . . INCONEL®. Capable of withstanding temperatures of up to 2000° F., INCONEL promised to give Scovill the long, trouble-free service they wanted.

The conveyor rolls were fabricated from extruded seamless INCONEL tubing. The finished roll dimensions are: 7 in. O.D. with 7/16 in. wall. Effective working width, including end guide collars, is 5 ft. 2 in. The rollers extend through the furnace side walls and are supported by anti-friction, self-aligning bearings.

Right now you may not be able to get all the INCONEL you want because so much is being diverted to defense work. But if you have a special high-temperature metal problem, Inco's Engineers will be glad to help you.

Write for your free copy of "Keep Operating Costs Down When Temperatures Go Up."

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

EMBLEM OF SERVICE INCO TRADE MARK

INCONEL ***. . . for long life at high temperatures***

NEW SUPER QUENCH OIL..

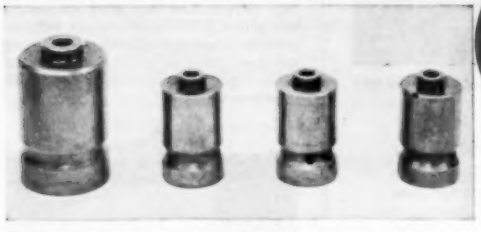
. . . GIVES YOU TRIPLE ACTION!

1 FASTER, DEEPER HARDENING

Mineral intensifiers give Park Triple A Oil faster quenching speed through the critical range, resulting in faster and deeper hardening.

2 LESS DISTORTION

Fast, uniform hardening in the critical range, plus a low cooling rate through the temperature zone of martensite formation, means less distortion from Park Triple A Oil.



Unretouched photographs of precision parts quenched from a carbo-nitriding furnace in Park Triple A Quench Oil. From left to right are parts quenched the first day, 30 days later, 60 days later, and 90 days later. Bright and clean after over 3 months use with no indication of reduction of surface cleanliness.

3 BRIGHT QUENCHING

Special anti-oxidants used in Park Triple A Oil give it greater stability for longer life and bright quenching properties. This is important when work is quenched from carbo-nitriding furnaces.

For Hot Oil Quenching up to 450° F use Park Thermo Quench Oil. Send for Bulletin No. F-7.

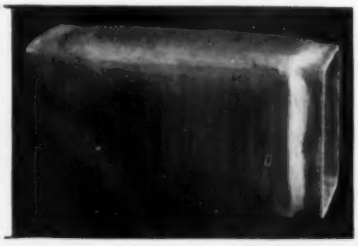
For These Critical Times . . .

Now more than ever you will need Park Triple A Quench Oil . . . with steels of critical hardenability due to lean alloy content and parts manufactured under government contracts, you can't afford costly rejects due to rigid inspection. Get the most from your quench oil — get Park Triple A Quench Oil today and save on critical material and expensive rejects. Send for Bulletin No. F-8 today, for complete information.

Park
CHEMICAL COMPANY

Three Refractory Cements For Lower-Cost Heat-Control

ALUNDUM* CEMENT — Electrically fused alumina in its most dense and unshrinkable form. Its high refractoriness, electrical resistivity, thermal conductivity and resistance to oxidation make it ideal for embedding electrical resistors, ramming burner blocks, setting bricks and lining certain metal melting furnaces.



Resistor around muffle imbedded in ALUNDUM cement

CRYSTOLON* CEMENT — A silicon carbide product that is an excellent heat conductor and highly resistant to spalling, slag adherence and penetration. Especially suitable for lining and patching non-ferrous metal melting furnaces and laying brick in zinc and zinc oxide furnaces.

Pit furnaces lined with Norton CRYSTOLON cement

MAGNORITE* CEMENT — Electrically fused magnesia and one of the most refractory oxides commercially available. Has high resistance to basic slags and is recommended for lining induction furnaces in which refractory metals and alloys — ferrous and non-ferrous — are melted.

High frequency induction furnace lined with MAGNORITE cement

Norton refractory cements have been developed to meet a wide variety of metal-working processes involving the use and control of heat. A Norton refractories engineer will be glad to specify the right cements for your applications. NORTON COMPANY, Worcester 6, Mass.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries.

NORTON

TRADE MARK REG. U. S. PAT. OFF.

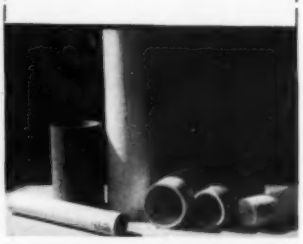
Special REFRACTORIES

Making better products to make other products better

Canadian Representative

A. P. GREEN FIRE BRICK CO., Ltd. TORONTO, ONTARIO

For high temperature furnaces... Super-Duty ALUNDUM Tubes



Norton keeps pace with steadily increasing temperatures in heat treating and sintering processes with a line of pure oxide refractories especially developed to withstand high heat.

Outstanding among these are ALUNDUM tubes (also cores and muffles) made of 99% fused alumina, providing excellent thermal conductivity and usable at temperatures up to 1950° C.

Norton Hearth Plates

are of CRYSTOLON (silicon carbide), selected for this important use because of its high refractoriness and great mechanical strength. CRYSTOLON hearths help reduce the refractory bulk within the furnace and have aided in increasing continuous furnace operating time from 4 weeks to 18 months or longer.

You'll find many helpful facts on Norton refractories, including bricks, burner blocks, cores and muffles in Bulletin 151. Write for it.

NORTON COMPANY
327 NEW BOND STREET
WORCESTER 6, MASS.

Metal Progress

Vol. 60, No. 1 · July 1951

Copyright, 1951, by American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio. Published monthly; subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $2.00. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, under the Act of March 3, 1879 . . . The American Society for Metals is not responsible for statements or opinions printed in this publication . . . Requests for change in address should include *old* address of the subscriber; missing numbers due to "change in address" cannot be replaced. Claims for nondelivered copies must be made within 60 days.

Ernest E. Thum, *Editor* John Parina, Jr., *Associate Editor*

Consulting Editors: Adolph Bregman, Harold J. Roast

Editorial Advisory Board

John Chipman Albert W. Demmler Muir L. Frey J. D. Hanawalt
Walter Jominy L. A. Lindberg Frank G. Norris Howard Scott

Cover by John S. Wozny

Technical Articles

Boron Steels for Constructional Parts and for Carburizing,
by Porter R. Wray 52

Leveling Solutions,
by Adolph Bregman 56

Nonferrous Castings Made at the U. S. Naval Gun Factory,
by Harold J. Roast 61

Radio-Autographic Determination of Lead in Stainless,
by L. R. Standifer and Mars G. Fontana .. 65

High-Frequency Heating of Forging Billets,
by Our Special Correspondent 70

Strain Rate Sensitivity of Molybdenum at Room Temperature,
by Robert Maddin and Robert Pond 76

Properties of Metals at Low Temperatures,
by Our Special Representative 79

Molybdenum, a New High-Temperature Metal,
by Robert M. Parke 81

Correspondence

Removing Carbonate From Cyanide Plating Solutions,
by Harry F. Ross 74

Oxygen for Blast Furnaces,
by G. Letendre 74

When Will It Fail?,
by T. T. Oberg 74

Bonding of Titanium Carbide,
by John C. Redmond 75

Metallurgy in Spain,
by Agustin Plana 75

Critical Points

It's Later Than You Think,
by The Editor 49

Metallurgists' "Collective Genius",
by Zay Jeffries 49

Departments

Data Sheet: Properties of Molybdenum,
by Robert M. Parke 80-B

Personals 98

Engineering Digest of New Products 29

Manufacturers' Literature .. .. .. 32-A & B

Advertisers' Index 152

Abstracts of Important Articles

Relation of Base Metal Surfaces to Plating Success 118

Abstract of "The Influence of Base Metal Surfaces on the Nature and Characteristics of Electrodeposited Metals", by A. T. Steer, a paper presented before the Australian Institute of Metals, Physical Metallurgy Division, 1949, as part of the Symposium on Electrodeposited Metals.

Series-Arc Welding 138

Abstract of "Welding with Multiple Electrodes in Series — A New Method of Unionmelt Welding", by A. R. Lytle and E. L. Frost, a paper presented at the American Welding Society annual meeting, October 1950.

Photoplasticity Studies of Pressure Working 146

Abstract of "Application of Photoplasticity to Modeling the Processes of Working Metals by Pressure", by S. J. Gubkin and S. I. Dobrovol'skii, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 91-93.

Don't Scrap PROFITS- from Scrap!

Today your DORMANT SCRAP* means more steel to help meet all-time high defense and domestic demands. Your country NEEDS it!

Today your DORMANT SCRAP* commands high prices.

HOW TO TURN SCRAP INTO MONEY...

with an organized dormant-scrap round-up in your plant:

1. Appoint a top executive with authority to make decisions to head the salvage drive.
2. Organize a Salvage Committee and include a member from every department.
3. Survey and resurvey your plant for untapped sources of dormant scrap. Encourage your employees to look for miscellaneous scrap and report it to the committee.
4. Sell your entire organization on the need to scrap unusable material and equipment.
5. Prepare a complete inventory of idle material and equipment. Tag everything not in use.
6. Start it back to the steel mills by selling it to your regular scrap dealer.
7. **KEEP AT IT!**

* Your DORMANT SCRAP is any obsolete, broken or wornout and irreparable machinery, tools, equipment, dies, jigs or fixtures, etc., that may encumber your premises. These, in the language of steel, are *scrap*, vital to steel production, and hence convertible into cash.

Steel is normally made from scrap and new pig iron in about a 50-50 ratio. The use of scrap means *better* steel, *faster* . . . because scrap has already undergone one refining process. Today under pressure of domestic and defense demands, the steel industry is consuming purchased scrap at the rate of 100,000 tons per day . . . an all-time high. *Your* dormant iron and steel scrap is *urgently* needed.

Round-up and sale of your dormant scrap NOW will benefit you, all steel users, and our country by:

1. Keeping the steel furnaces producing at their highest rate in history.
2. Conserving our vital iron ore reserves. The *more* scrap used in steelmaking, the *less* ore needed.
3. Making *better* steel, *faster*.

INLAND

INLAND STEEL COMPANY

38 South Dearborn Street • Chicago 3, Illinois

Critical Points

BY THE EDITOR

It's Later Than You Think

IT IS A COMFORTABLE statement we read at frequent intervals in the business press that the ingot capacity of the American steel industry will be expanded from its present enormous 104 million tons to 117.5 million by the end of 1952 — just about one third greater than the amount needed to win World War II. That, apparently, should mean enough for every use (even coke dispensers). Apparently that is what the governmental planners are trying to accomplish with their DO orders and their "controlled materials plan".

Let it be understood immediately that the over-all production of 100,000,000 tons of ingots means the shipment of 70,000,000 tons of rolled shapes, and that only 5% of the latter represent alloy steels for a peacetime economy. Let it also be understood immediately that the pinch is hardest in this 5%. Lucky is he who only needs carbon steel!

There are several reasons for the pinch in alloy. Even if the government were not accumulating stockpiles of the various elements, the Army, Navy and Air Forces use large amounts of alloy steel, and the fairly rich ones at that. Then, too, there is the jet engine program which needs superalloys. All in all, there will be very, very little left for civilians.

The words "will be" should be IS. The shortage is *now*, not when the controlled materials plan is screwed up to its last notch. Parsimonious use of alloys is necessary *today*, not tomorrow when your inventories are running low.

Members of the American Society for Metals are the men who can practice immediately those conservation steps outlined in the panel discussion reproduced in last month's *Metal Progress*. Each part in manufacture should be scrutinized and made of the leanest steel that has adequate properties. Use the H-bands to the utmost. Heat treatments should be modernized; ancient methods can no longer be bolstered with high alloy. Segregate the scrap, so steelmakers can reclaim tramp alloy for triple-alloy steels. Give the boron treated steels a try — even boron treated carbon steel is plenty good enough for many an alloy steel part.

Repeat — *Now* is the time, not tomorrow!

Metallurgists' "Collective Genius"

GUEST EDITORIAL

THE PRESENT world crisis will be resolved dramatically if there is an all-out "hot war" — or it will evolve gradually toward a livable peace.

If there is to be a large-scale war, metals, as in the past, will play a major role in the outcome. If an all-out war is to be avoided, the free world must increase the supply of metals and use efficiently both the new metal production and all of the practically available scrap. This could so enhance the potential military power of the free peoples that an aggressive attack by Russia would be virtual suicide.

The production mobilizers in the free world have been and are implementing plans to increase the metal supply. In tonnages, the most important increases will be in steel and aluminum, but no metal needed in our complex economy is being neglected.

Many groups are essential in making optimum use of these metals, including managers, designers of end products, allocators, inventors, transportation teams, production teams, but one group that must be counted on for efficient utilization is the metallurgists.

Fortunately, metallurgical art and science in the free world are in good health. This is one result of freedom's fertile soil for the growth of "collective genius". Just as a group advances an art or science faster than an individual, so do many groups working along the same line progress faster than one group. By exchanging the results of experience and experiment, by discussing theories, and by the cross fertilization of ideas, the collective genius completely eclipses the individual genius no matter how great may be his stature. The individual genius does not become less important in this scheme of information and idea dissemination — his contributions actually become *more* important to society when he participates in group effort.

It is felt that the World Metallurgical Congress, which is to be held in Detroit in October, will provide an opportunity to further the benefits of collective genius in metallurgy in the whole free world, and bring nearer to realization that cherished goal of decent people on this earth — peace with freedom.

ZAY JEFFRIES
Past President
Director General
World Metallurgical Congress

Boron Steels for Constructional Parts and for Carburizing

By Porter R. Wray*
Metallurgical Engineer
(Alloy Steels)
United States Steel Co.
Pittsburgh

BECAUSE OF THE NECESSITY for conserving the critical alloying elements, nickel, chromium, and molybdenum, the American Iron and Steel Institute, on Feb. 12, 1951, announced two new series of steels containing a proper amount of boron. These steels, known as 80Bxx and 81Bxx, are low nickel, chromium, molybdenum compositions, in which boron has replaced about half of the critical alloy content of the 86xx and 87xx steels which were the basic National Emergency steels of World War II.

The 80Bxx steels match the hardenability of the older 86xx and 87xx triple-alloy steels, and the 81Bxx will match the 41xx steels. Consequently they should be able to replace 70 to 80% of the present constructional alloy steels on an equivalent hardenability basis. It is still too early to state whether the composition of these steels will have to be altered slightly, based upon production experience, since only a handful of production heats has been made, but so far their hardenability seems to be exceeding the limits predicted from laboratory data.

In addition to the 80Bxx and 81Bxx series, four additional boron steels are showing promise. These are 94B17 and 94B20 for carburized parts formerly made of 4620, 43B17 as a replacement for 4820 in carburized parts of heavy-duty trucks, and 86B45 as a possible replacement for 4340. The United States Steel Co. has also developed some interesting carburizing steels which will be described at some length in the second half of this article.

Hardenability — The Metals Handbook concisely describes the role of boron in steel as follows: "Boron is used in steel for one purpose only — to increase the hardenability; that is, to increase the depth to which the steel will harden when quenched. Only a few thousandths of a per cent is ordinarily added." In Fig. 1, typical end-quench hardenability curves of 8645, 8645 plus boron, and 4340 illustrate its potent effect; it is evident that boron can replace several hundred times its own weight of other hardening alloys, such as manganese, chromium, molybdenum and nickel. In the example shown, 0.0012% boron in a normal 8645 steel is contributing the same hardenability effect as 1.33% nickel plus 0.31% chromium plus 0.04% molybdenum, or a total of 1.68% of alloy.

Since the effect of boron on hardenability decreases with increasing carbon, it is a more effective conserver of critical alloys in the lower carbon steels. The carburizing grades of alloy steel having less than 0.30% carbon are obviously a more fertile field than spring steels at 0.60% carbon.

Grain Growth — Boron tends to lower the austenite grain coarsening temperature, and, in some of the early work, this effect caused undue alarm. This tendency can be counteracted by a judicious increase in the aluminum addition used for grain size control.

Annealing — In respect to its influence on annealing, boron as an alloying element is unique: It delays the start of transformation appreciably while delaying completion only slightly. This has a practical application in that a lower alloy steel containing boron can replace a higher alloy steel to obtain the same properties when hardened, yet the boron steel can be annealed with a much shorter cycle. Such steels are also softer than the higher alloy steel in the as-rolled or normalized condition, provided the size is sufficiently large that air quenching does not occur in normal mill practice.

Robbins and Lawless reported that they had been able to cut their annealing time and costs on hand tool parts in half by changing to the boron steel described below under "Workability".

*The writer is indebted to his associates on the technical committee of alloy steel bars of the American Iron and Steel Institute and the iron and steel technical committee of the Society of Automotive Engineers, wherein much of this work is being planned and developed, and to R. A. Grange and J. F. Boyce of the United States Steel Co. Research Laboratory for their many valuable contributions to our knowledge of the effect of boron on the properties of steel.

They also reported improved machinability due to obtaining a more desirable structure in the boron steel.

Tempering Behavior — Boron in the amounts normally used does not increase the resistance to softening on tempering as do other alloying elements (particularly vanadium, molybdenum, or tungsten); in fact it is usually necessary to

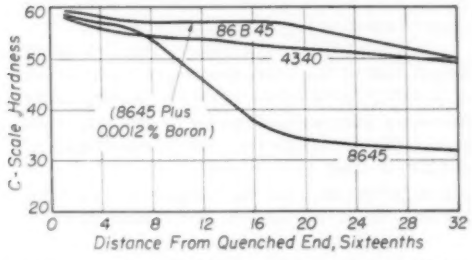


Fig. 1 — Jominy End-Quench Curves Showing That 0.0012% Boron in 8645 Increases Hardenability to Above That of 4340 Containing 168 Points More Alloy

use a *lower* tempering temperature to obtain a given hardness and strength. Thus, the tempering temperature for 1045 plus boron had to be lowered 100 to 150° F. to match the hardness of quenched and tempered A.I.S.I. 9440. In a similar manner, 150 to 200° F. lower tempering temperature was necessary with 1345 plus boron to match the hardness of 4145.

WORKABILITY

Boron steels have very desirable processing characteristics, such as forgeability, ease of cold heading, descaling and machining. Robbins and Lawless of Plomb Tool Co. reported in *Metal Progress* (January 1950, p. 81) on the forging of wrenches from 1045+B steel in comparison with 9445 steel formerly used. Number of 9445 parts per die-sink was 13,000 to 15,000; of 1045+B parts was 22,000 to 25,000. The 1045+B steel had a lighter and less adherent scale, which was easier to remove than the scale on the 9445 steel, and required 30% less pickling.

The above performance is probably the result of the lower total alloy content of the 1045+B. Metallurgists in other shops concur that the boron steel behaves the same as the base composition without boron — that is to say, 1045 plus boron works similarly to 1045.

Glen C. Riegel of Caterpillar Tractor Co. reports the use of hundreds of tons of 1035+B for cold headed bolts and capscrews, replacing 8640, as shown at the top of the next column.

	8640	1035+B
Trimmer dies, pieces per grind	9,000	22,100
Shear dies, pieces per grind	150,000	400,000
Pointer cutters, hr. per grind	1	4
Rolled thread dies per grind	150,000	200,000

Since these bolts develop the same properties when heat treated, the lower alloy content (about 1¼% less) of the 1035+B led to real shop economies.

While some of the above examples may be extreme, it is fundamental that although a very small quantity of boron can replace a large quantity of other alloys and develop the same properties after quenching and tempering, the lower total alloy content usually improves the hot or cold forming, annealing, descaling and machinability characteristics of the parts.

NEW CARBURIZING STEELS

Some interesting research and development work has been done on the carburizing steels to find a steel with hardenability comparable to 3310 and 9310, yet minimize undesirable characteristics such as retained austenite and undissolved carbides after routine carburizing and hardening. United States Steel Co. developed a steel known by the trade name "USS SuperKore A", which is essentially a 4312 plus boron and 0.03 to 0.07% vanadium. Figure 2 shows the hardenability of four heats of SuperKore A; they fall within the top half of the hardenability band of 3310H, even though the new steel has 2.5% total alloy and the 3310H has 5%.

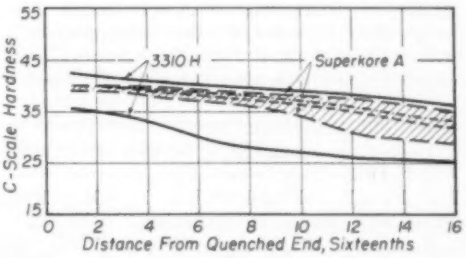


Fig. 2 — Hardenability of Four Heats of USS SuperKore A Is on the High Side of the Band for 3310H. (Note that horizontal scale is twice that of Fig. 1)

	SuperKore A (Tested)	3310H (Range)
Carbon	0.12 to 0.14	0.07 to 0.014
Manganese	0.65 to 0.87	0.35 to 0.65
Silicon	0.16 to 0.35	0.20 to 0.35
Nickel	1.63 to 1.83	3.20 to 3.80
Chromium	0.48 to 0.51	1.35 to 1.75
Molybdenum	0.23 to 0.24	None
Vanadium	0.03 to 0.07	None
Boron	Yes	None

Pratt and Whitney Division of United Aircraft Corp. has thoroughly tested the new steel for heavy-duty gears, shafts, and pinions for large air-cooled engines, and it is approved for aircraft use under Aeronautical Materials Specification No. 6266. Pratt and Whitney's metallurgists reported improved carburizing characteristics — much less retained austenite and undissolved carbides after direct quenching. The Mack Mfg. Co. has had similar success with this steel; transmission countershafts for heavy truck transmissions have been in service for five years without difficulty.

Carbon penetration into SuperKore is about the same as into conventional carburizing steels, as will be evident from the following tabulation of carbon penetration of USS SuperKore AA (4317+B) and 3310 when gas carburized 17 hr. at 1700° F. Hardness at respective depths is higher in the boron steel — especially near the surface, due to the more complete transformation of austenite during quenching.

Depth	Carbon Content		Quench Hardness	
	4317+B	3310	4317+B	3310
0.006 in.	0.98	1.06		C-37
0.010	1.00	1.04		
0.020	0.94	0.98	C-59	C-47
0.040	0.80	0.83	C-64	C-57
0.060	0.66	0.66	C-65	C-61
0.080	0.50	0.50	C-63	C-60
0.100	0.35	0.33	C-57	C-54
0.120	0.26	0.22	C-51	C-48
0.140	0.20	0.17	C-46	C-44
0.160	0.16	0.12	C-43	C-42
0.180	0.14	0.10	C-41	C-41
0.200	0.13	0.10	C-41	C-41

United States Steel Co. has extended this development to steels of lower alloy contents, such as SuperKore B (4615 plus boron) and SuperKore C (8615 plus boron) with results comparable to the above. Our work over the past four years has shown that lower alloy steels containing boron will have the same core properties as the higher alloy steel they match in hardenability, and at the same time the boron steels are easier to forge, anneal, machine, and to heat treat after carburizing because of their lower total alloy content.

We have encountered two problems associated with boron in the carburizing steels that deserve mention here as a guide to others.

Hardenability of the Case — The first problem is that of the hardenability of the case. It is known that boron's effect on hardenability decreases with increasing carbon content. This means that although the *core* hardenability of a 1321+B steel (for example) is similar to a higher alloy steel (in fact greater than 3316), the *case* from 1% carbon and higher has the hardenability of 13100. This deficiency of hardenability might cause soft spots on heavy sections — or on smaller sections, fixture quenched.

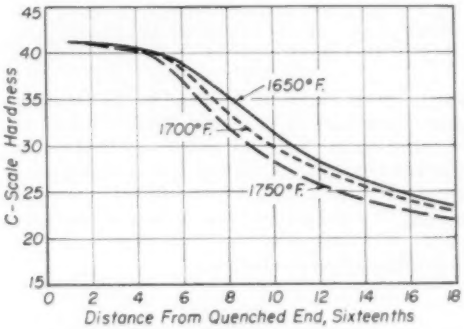


Fig. 4 — Hardenability of 86B20 Is Impaired by Long Stays at High Temperature. Treatment: Pseudo-carburizing in vacuum for 17 hr. at temperatures indicated. Note extended horizontal scale in Fig. 4 and 5

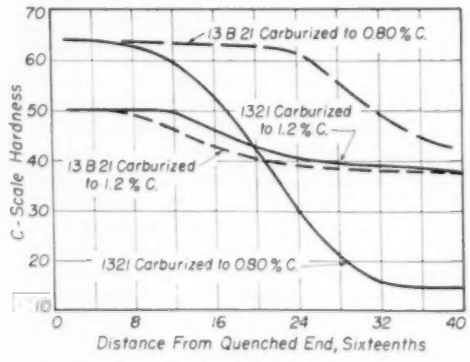


Fig. 3 — Case Hardenability of Boron Treated Steels Is Impaired at Carbons Above 0.80 or 0.90%

Whether this will be a serious shortcoming can only be determined on production parts.

One method for minimizing this behavior is to limit the carbon in the case to a predetermined maximum. Thus, Fig. 3 shows that boron in 13xx does not improve the hardenability at 1.20% carbon, while it does have a very pronounced effect in the same steel at 0.80% carbon. (Recent work indicates that, in some steels, a limit of 0.90% carbon will suffice.) The reward from limiting the maximum carbon content of the case is quite promising. At least one manufacturer of large trucks is now using this technique quite successfully, although the metallurgists planned it for different reasons.

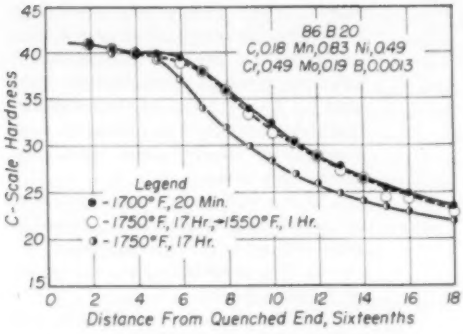
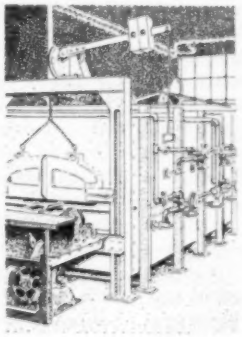

86 B 20
C,018 Mn,083 Ni,049
Cr,049 Mo,019 B,0003
Legend
● - 1700° F, 20 Min.
○ - 1750° F, 17 Hr., 1550° F, 1 Hr.
◑ - 1750° F, 17 Hr.
C - Scale Hardness
Distance From Quenched End, Sixteenths

Fig. 5 — Hardenability Recovered by Slow Cooling to 1550° F. Before Quenching (or Reheating to 1550° F. and Quenching)

APPARENT LOSS IN CORE HARDENABILITY ON DIRECT QUENCHING FOLLOWING CARBURIZING

Concerning the second problem, R. A. Grange and T. M. Garvey first reported in *Transactions* ⊕, 1946 (V. 37, p. 136) that heating to high temperatures sometimes resulted in a partial or complete loss of the hardenability effect of boron. Grange has also found this effect in carburizing steels containing boron after long heating at carburizing temperatures followed by direct quenching. For example, Fig. 4 shows a series of hardenability curves of 8620 containing boron. Samples (Jominy test pieces) were pseudo-carburized (heated in vacuum) for 17 hr. at the temperatures indicated and end-quenched. Notice that the higher the soaking temperature, the lower is the hardenability.

In Fig. 5, the curve for the sample pseudo-carburized at 1750° F. is replotted along with one obtained by a normal hardening treatment of 20 min. at 1700° F., followed by quenching, as well as a third curve obtained by pseudo-carburizing 17 hr. at 1750° F., slow cooling to 1550° F. (that is, equalizing at 1550° F.), followed by quenching. Notice that the loss in hardenability encountered in the direct quenching from the carburizing temperature is recovered by slow cooling to 1550° F. prior to quenching. (Patent has been applied for for this heat treatment.) Another sample was pseudo-carburized for 17 hr. at 1750° F., slow cooled to room temperature, reheated to 1550° F. and quenched. Since this sample developed the full hardenability of the one quenched after 20 min. at 1700° F., it was not plotted in Fig. 5.



It is anticipated that production results will confirm the beneficial effects of this equalizing treatment; in fact, it will also help control the distortion. The mechanism of this phenomenon (temporary suppression of enhanced hardenability) is still a matter of conjecture.

SUMMARY

For the majority of applications for the constructional alloy steels, boron can probably replace a sizable quantity of nickel, chromium, molybdenum, and other critical alloys where their presence is necessary only for adequate hardenability. Other advantages are *(a)* improved hot and cold working, *(b)* shorter annealing cycle, and *(c)* improved machinability. In carburizing steels, boron shortens the time cycle for annealing and minimizes the amount of retained austenite and undissolved carbides in the carburized case.

Boron steels require more care in selection and treatment than conventional alloy steels because of the following considerations:

1. Hardenability must be adequate, so that a tempered martensitic structure is obtained at the location of highest stresses. If other microstructures are obtained, the mechanical properties (particularly toughness) may be impaired to an even greater extent than in conventional alloy steels.

2. Boron exerts little or no effect in retarding softening at elevated temperatures. This usually necessitates a lower tempering temperature to attain a desired hardness or strength. Boron steels are not "high-temperature" steels.

3. Because of a decreasing influence of boron with increasing carbon content, the hardenability of the case of a carburized part may be insufficient. Some improvement can be effected by limiting the maximum carbon in the case to about 0.90% carbon.

4. Carburizing, followed by direct quenching, may decrease the hardenability of the core. Either delayed quenching (that is, slow cooling to about 1550° F. prior to quenching) or a conventional double treatment seems to be an effective remedy.

5. Several new boron alloy steels have been developed to conserve our critically short alloys. By concentrated attention to details, it is felt that these steels will have fairly wide application. ⊕

Leveling Solutions

By Adolph Bregman
Consulting Engineer
New York City
Consulting Editor for *Metal Progress*

DURING the past two or three years, a growing interest has been evident in the electroplating industry in the use of the new solutions which give a deposited surface that is smoother than the base upon which it is applied. This action is termed "leveling" or "smoothing". Its primary advantage is the saving of labor in polishing and buffing.

It must be noted at the outset that the "level" surface is not necessarily a bright surface; it is not comparable to the bright nickel and copper plates which are in wide use. The level coating tends to even out any existing scratches, dents, and pits in the basis metal to such an extent as to make polishing and buffing relatively minor operations, especially in comparison with the work which was formerly necessary to remove such imperfections from the basis metal. However, it will require some final buffing, in order to provide the luster required for a decorative coating on the article.

Leveling action is a function of the bath composition and operating conditions. The Watts' bath with no additions, for example, has no leveling action. Some organic addition agents promote leveling action, but, at the same time, introduce other factors which may be undesirable.

It is well known that the bright nickel baths in general commercial use have some leveling action, although only to a limited extent in the lighter or so-called "commercial" thicknesses generally applied. As the deposit is increased in thickness, this leveling action is improved. G. E. Gardam states in his article "Smoothing Action as a Mechanism in Bright Nickel Plating" (*Journal*, Electrodepositors Technical Society, V. 22, 1946-47) that the smoothing action of bright-nickel solutions normally operates on a very small, probably microscopic, scale. It has been previously noted that the mechanism of smoothing action of the BNF bright-nickel solution on rough matte deposits consists in the growth of hemispheres that become larger in diameter and hence more nearly plane with continuing deposition.

When solutions containing zinc or cadmium are used, the action is quite different in three respects:

1. The brightening is very quick on rough deposits.
2. The final result is usually not fully bright.
3. In some cases the rate of brightening increases when the deposit is increased in thickness. This suggests that the action is the filling up of big hollows without affecting or even increasing tiny corrugations.

Another and very important aspect of the leveling problem is the effect of the surface condition of the base metal on the deposit. It has long been known that the surface has a decided bearing on the subsequent plate. G. B. Hogaboom ("Principles of Electroplating and Electroforming", by Blum and Hogaboom, p. 89 and 127) revealed this as early as 1916, and similar observations were later made by W. Blum, H. S. Rawdon, A. K. Graham and A. W. Hothersall.

This principle has also been recognized by A. T. Steer (see p. 118 this issue for abstract of his article). He states that a surface having the property of equivalent capture of ions (in other words, having a surface amenable to deposition which will accept a plate and keep it firmly adherent) automatically produces a smoothing action. This smoothing action does not induce deposits to fill large cavities and build up a level deposit, but confines its action to the very early stages of deposition and, in such case, causes the minute irregularities of a surface to be filled before any deposition is effected on the high points of the surface.

Thus, in the first few seconds of deposition, ion capture takes place in these irregularities and so builds up the deposit until the high points are reached, when the deposition becomes essentially smooth and level. To cite an instance, Steer recommends, in order to make the surface amenable to the deposition of an adherent and even deposit on 60-40 brass, the use of a pretreatment consisting of a weak aqueous solution of phosphoric acid (1¼%)

with an inhibitor and a wetting agent.

It is noteworthy that an important aid in the production of level deposits is the comparatively recent practice of polishing the base metal in the flat, thus reducing the polishing cost by the use of automatic polishing which is easily applicable to flat stock. This practice may be said to "reduce the load" on the plating solution. Outstanding applications, for example, include forgings and castings on which heavy preliminary grinding had to be done.

LEVEL DEPOSITS AND SUBSEQUENT BUFFING

When the leveling solution first appeared, its advantages were so apparent that the entire industry went to work and climbed aboard the bandwagon. Consequently, a number of methods have been recommended, brief summaries of which follow.

One of the earliest baths of the leveling type is the Perflow, a Watts-type solution with addition agents. It has the property of filling-in scratch marks and, in most cases, some of the polishing steps in the preparation of the base metal prior to plating can be eliminated. As a result, there are considerable savings — fewer finishing wheels and compounds are used, less finishing equipment is required, and important savings in labor are evident. Extensive production experience is said to have proved that as high as 70% of the cost of buffs and buffing compounds and 50% of buffing labor costs are eliminated in the final nickel finishing, since the semibright, soft Perflow deposit is so easily color-buffed to a brilliant finish.

A recommended solution composition for this bath is as follows:

Single Nickel Salts ($NiSO_4 \cdot 6H_2O$)	30 to 60 oz. per gal. (as required by current density limitations. Normal operating range 36 to 45 oz. per gal.).
Nickel Chloride ($NiCl_2 \cdot 6H_2O$)	5 to 7 oz. per gal. (normal operating range 5 to 6).
Boric Acid (H_3BO_3)	5 to 5.5 oz. per gal.
XXX Solution-D	0.25 to 0.5% by volume.
Perflow Addition Agent	0.5 to 1.1 lb. per 100 gal. (as determined by local agitation rate and current density limitations).
Formaldehyde	0.2 to 1.0 qt. per 1000 gal.
pH	3.5 to 4.2.
Temperature	120 to 135° F.
Current Density	20 to 100 amp. per sq.ft.

In the comprehensive discussion "Surface Contour and Leveling", by A. H. DuRose, W. P. Karash and K. S. Willson (*Proceedings*, American Electroplaters Society, 1950, p. 193) leveling is treated from a mathematical aspect, including atomic force characteristics. The relationship between thickness of the deposit and leveling for various solutions is described, as well as methods of evaluating "flowing" and "cutting off" of metal in buffing; also, the effect of surface texture on buffing.

It is stated in this paper that all electroplates produce some leveling effect. Variations are caused by excessive roughness of the deposits in a nickel solution with excessive thickness or improper operation.

An investigation into the buffing of three types of nickel deposits — gray, high-chloride gray, and semibright — disclosed that the semibright was easiest to buff. Nickel is buffed by a cutting or dragging-off action of the buff; copper and tin by plastic flow.

PERIODIC REVERSE PLATING

The fundamental factors affecting leveling with periodic reverse plating include the PR cycle, current density, thickness of deposit, agitation, solution composition, addition agents and solution contamination. These are described by G. W. Jernstedt in "Leveling With PR Current Plating", *Proceedings*, American Electroplaters Society, 1950. See also "Periodic Reverse Current Electroplating", by Adolph Bregman, *Metal Progress*, August 1950, p. 199. The effect of leveling with the PR process on the orange peel resulting from drawing operations is noteworthy. Leveling is advantageous with heavy copper deposits, such as the 0.040-in. thick stampers in use in the record industry.

The effect of PR plating upon the leveling of deposits in the plates using cyanide electrolytes, copper, brass, and silver solutions have been summarized by Jernstedt as follows:

1. The longer reverse or deplating periods, the better the leveling action.

2. The higher the current density, the better the leveling effect. The optimum in a copper cyanide solution is from 50 to 75 amp. per sq.ft. at 150° F.

3. The heavier the deposit, the greater the leveling effect, up to a certain point. The optimum is between 0.001 and 0.002 in.

4. Agitation by air greatly improves leveling.

5. Solution composition is not critical except keeping the solution at its maximum efficiency. The use of the inorganic addition agent "Wes-X" is recommended.

6. Organic and metallic impurities have a

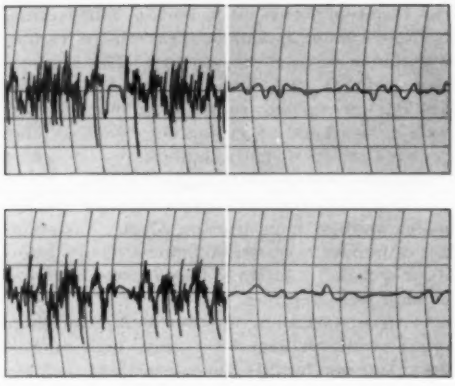


Fig. 1 — Leveling Effect of Periodic Reverse Copper Plating. (Top left) Original steel, RMS range 18 to 26, average range 24. The same steel after periodic reverse plating in "Wes-X" (top right) had an RMS range 3 to 6, average 5, deposit 0.0009 in. thick. (Bottom left) Another sample of steel had an RMS range 18 to 26, average 22. After plating in "Wes-X" PR copper to 0.0018 in. thickness, its RMS range was 2 to 4, with an average of 3 (bottom right)

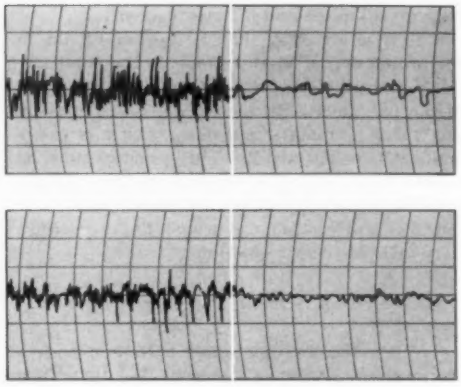


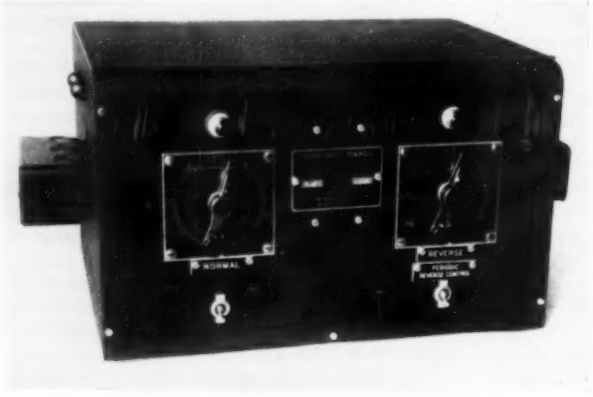
Fig. 3 — Leveling Action of Cobalt-Nickel Deposits. (Top left) Original steel, RMS range 20 to 24, average range 22. The same steel after plating in 9-H standard nickel solution (top right) had an RMS range 7 to 9, average 8, deposit 0.0002 in. thick. (Bottom left) Another sample showed an RMS range 13 to 17, average 15. After plating in 9-H standard nickel solution (bottom right) to a thickness 0.002 in., the RMS range was 4 to 6, with an average of 5

deleterious effect. Figure 1 shows graphically the effect of PR on copper plating.

Since the advent of NPA restrictions on the use of nickel, many who, heretofore, copper, nickel and chromium plated their parts are now thinking seriously of plating chromium directly over copper deposits, as permitted by NPA Order M-12. Although this finish is not the equal of copper-nickel-chromium, especially for outdoor exposure and sulphur-laden atmospheres, data on "PR-Wes-X" deposits are said to have indicated that good corrosion resistance can be obtained by this sequence. New modifications of the PR process are said to have made possible a degree of leveling never before attained in plating, resulting in a compact, nonporous deposit distributed well over the work. Deposits of 0.00001 to 0.00002 in. of chromium over copper are recommended.

It has been found that PR plating is improved by using lower current densities in the reverse phase of the cycle than in the direct phase. The periodic reverse current controller, Fig. 2, operates by reversal of field excitation current in which the resistance can be varied to change the current density in the deplating phase of the cycle. This unit is adaptable to various conditions, permitting complete control by seconds up to 3 min. of the direct and reverse phases.

Fig. 2 — Hanson-VanWinkle-Munning Type TR Instrument Controls Standard Size Generators by Reversal of Field Excitation Current



Frank C. Mesle has cited, on page 167 of the 1950 *Proceedings* of the American Electroplaters Society, an interesting experience with the use of PR plating with silver. In producing a dull plate on spoons, he could effect smooth deposits up to 100 amp. per sq.ft. using PR, whereas by direct plating he had been limited to 50 amp. per sq.ft. with the same smooth-

ness; but if he added a brightener, approximately 1 ml. per gal. of thiosulphate, he could plate at 100 amp. per sq.ft. with or without the use of periodic reverse action.

COBALT-NICKEL SOLUTIONS

Cobalt-nickel solutions have leveling properties in bright or semibright deposits. Good leveling is favored by high temperature, vigorous agitation, and high metal content. Nickel chloride in excess of about 8 oz. per gal., various metallic and organic impurities, and ammonium compounds are detrimental in this type of bath. Formic acid accounts for the main leveling effect. Formaldehyde is used to obtain brightness but does not affect leveling. Physical properties and corrosion resistance are substantially the same as those of cobalt-nickel deposits from solutions in general use. The leveling action of a cobalt-nickel solution is illustrated in Fig. 3.

Dr. Louis Weisberg has reported on this type of bath, making surface measurements with a Brush surface analyzer using a diamond point stylus. He made all measurements at right angles to the polishing direction, taking five readings on each piece and reporting the average of the five, in order to eliminate variations and irregularities. He used, as a reference base, a purified Watts solution which produced no leveling effect whatever.

A recommended solution (U. S. and foreign patent applications are pending) consists of:

Nickel sulphate	48 oz.
Nickel chloride	4 oz.
Formic acid	2 oz.
Boric acid	5.5 oz.
Cobalt sulphate	0.4 oz.
Formaldehyde solution (40%)	0.35 oz.
pH (for semibright plate)	2.3 oz.
Temperature, 160 to 170° F.; current density, 40 amp. per sq.ft.; anodes, cobalt-containing.	

It is important to maintain agitation of the solution by air or by moving the solution. Workbar motion alone is insufficient. Impurities, including organics, must be kept out, as traces of oil will completely destroy leveling action. They can be removed with activated carbon, after which the solution will operate satisfactorily. Some brighteners also destroy leveling action. Wetting agents seem to be of no assistance in leveling. Ammonia and its salts should be excluded because they are harmful.

An interesting fact is that the results vary widely between the laboratory and the plant. In some large plants, commercial operations have given better results than the laboratory, perhaps because the agitation was better than in the laboratory.

ELECTROLYTIC AND CHEMICAL POLISHING

Electrolytic and chemical polishing have been recommended by C. L. Faust as methods of leveling electrodeposits previously applied. The microroughness, according to profilometer, Brush surface analyzer, and reflectivity measurements — as well as microscopic examination, before and after electropolishing or chemical polishing of steel, brass, and aluminum-base metals, and before and after chemical and electropolishing of nickel plate — show that chemical and electrolytic means often produce better reflectivity than mechanical. Nonmechanical methods also remove microscopic debris and nonmetallic particles left by mechanical polishing. An interesting application of electropolishing is in the preparation of bearing liners for producing smooth bearing surfaces.

Myron B. Diggin has reported that no leveling effect was discernible in 10% and 50% sulphuric acid solutions. In a sulphuric–phosphoric–water solution, there was marked leveling; in 66% sulphuric acid, a slight leveling effect. In addition, Diggin has also presented data on several different methods of producing level deposits. The leveling produced by various electroplating baths in tests made over a period of two years is shown in the table on p. 60.

R. F. Ledford has commented that, for some time, it has been assumed that there is leveling, or surface smoothing, in barrel plating. He has

Antimony Plate

Correction

IN THE ARTICLE on antimony plate by Adolph Bregman, which appeared in our February issue, pages 245-247, it was stated that antimony plate is resistant to hydrofluoric acid. This statement was an editorial error. Antimony is not resistant to hydrofluoric acid. While antimony is not readily attacked by HF in the absence of air, in the presence of air or any oxidizing agent, its resistance is very poor.

reported work on barrel plating in zinc solutions to develop data on the degree of smoothing obtainable, if any, and to determine the cause of said smoothing. Several samples were still-plated in a zinc solution of a composition similar to that used in barrel plating. The surface smoothness after plating was found to be consistently much less than before plating, indicating absence of leveling. From these data, the conclusion was reached that the smoothing action in barrel plating is probably due to burnishing and not to electrochemical action.

SURFACE MEASURING INSTRUMENTS

An important adjunct in the operation of leveling solutions is, of course, the instrument for measuring the characteristics of the deposited surface. Such instruments include:

1. The microscope for perpendicular viewing with oblique lighting parallel to and perpendicular to surface, and for examination of cut edges mounted in plastic, ground, polished, and etched by usual metallographic procedure, and examined either perpendicularly or at an angle to the surface.

2. Tracer methods by the Brush Analyzer and the Profilometer.

3. The replica method, both by comparison of replicas with Fax Film equipment and evaluation of replicas by Herschman apparatus. It is noteworthy that in profile measurements, the diamond point tends to flatten out soft metals, giving misleading readings. By the replica method, a plastic reproduction of the surface is obtained which, for visual inspection, is free from the glare of a polished metal part. It has been pointed out that there is poor correlation between the results from reflectometers and profilometers.

A recently suggested device for determining the smoothness or "surface truth" involves the clarity of the image reflected by the surface, as distinguished from the brightness or intensity measured by the conventional reflectance methods.

The apparatus consists of an electric lamp contained in a box, the front of which is a screen of paper ruled with a right-angle pattern of alternate black and clear stripes of equal width. This surface is held in front of the screen at a distance giving a clear reflection of the pattern. As the article is withdrawn, a point will be reached where the reflection of the bright squares and black stripes cannot be distinguished. At this point, the distance between the screen and the article is measured.

The measurement of surface roughness with the interference microscope has been described by Strang and Ogburn.

Other instruments include acoustical devices and the electron microscope. Kellner's paper (*Proceedings*, American Electroplaters Society, 1950, p. 105) gives an excellent summary of all the methods and types of equipment available for surface measurement.

Leveling in Electroplating Solutions

Solution	Deposit Thickness in Inches	Average Profile RMS* Micro-Inches		Reduction in Profile RMS* Micro-Inches
		Steel	Deposit	
Nickel:				
Cold	0.001	28	25	3
Watts', purified	0.001	18	18	0
	0.002	17	21	−4
	0.0025	21	33	−12
Bright, organic No. 1	0.001	23	19	4
No. 2	0.002	23	13	10
No. 3	0.0012	30	11	19
Semibright, organic†	0.001	38	6	32
	0.002	38	4	34
Chloride-acetate	0.001	23	20	3
	0.002	23	20	3
All-chloride	0.001	25	29	−4
Fluoborate, not purified	0.001	29	15	14
purified	0.001	36	33	3
Cobalt-nickel	0.001	21	8	13
	0.003	18	3	15
Copper:				
Rochelle	0.001	18	26	−8
Rochelle, with 4:1 PR	0.001	18	12	6
Bright, potassium cyanide	0.001	18	21	−3
Bright, cyanide, PR, no organics†	0.0015	13.1	2.5	10.6
Sulphate	0.001	18	35	−17
0.16 oz. per gal. molasses	0.001	17	19	−2
Bright, sulphate	0.001	22	17	5
Cadmium:				
Cyanide	0.0005	18	37‡	−19
with brightener	0.001	17	11	6

*Root mean square. †Data from outside sources.
‡Deposit too soft for accurate measurement.

Nonferrous Castings Made at the U. S. Naval Gun Factory

By Harold J. Roast
Bronze Foundry Consultant
Consulting Editor for Metal Progress
London, Ontario

A VISIT TO ANY NATIONAL INSTITUTION suggests the advisability of becoming acquainted with its background. This, in the case of the Washington Navy Yard (called since 1945 the U. S. Naval Gun Factory) proves to be fraught with unusual historic interest.

The Washington Navy Yard started in 1799 as the production and maintenance arm of the embryonic United States Navy, which was having to meet the depredations by the French on American shipping, and to conduct an undeclared war on Tripoli and the pirates. During the War of 1812 the British captured Washington, and this forced the then Secretary of the Navy to order the yard burned to prevent its stores, especially powder, from falling into the hands of the enemy. By 1816, however, a new Yard had arisen including a 1900-ft. workshop, another building with 22 hand forges and a steam-operated hammer, and a few other general facilities. As shown by the early view, Fig. 1, little more was done up to the Civil War, which made further demands on the Yard workers, especially in the production of armor plate, which increased rapidly toward the end of the war.

In 1883 construction commenced on what history calls the New American Navy. Guns, gun mounts, shells, ammunition hoists and torpedo tubes for this fleet became the main items of production. Development of all details has since been continuous. For example, electric firing was installed in guns during the Spanish-American war. In World War I came orders for 14-in., 50-caliber guns, experimental batteries for 18-in. guns for battleships, and for wireless equipment — to mention only a few. The Yard is especially proud of its rapid design and construction of long-range guns of naval type, mounted on railroad cars, and used by Pershing's army in France.

Naturally, the Yard's facilities and production were enormously increased to meet the demands of World War II. Its present plant is illustrated in the airplane photograph reproduced as Fig. 2. Its 188 buildings on 125 acres constitute the world's largest naval armament plant.

Since 1945, the time at which the name was changed to the U. S. Naval Gun Factory, a great variety of items have seen their birth and final development under the ever-widening scope of the Factory's personnel and equipment. The latest activities include optical instruments, depth charge projectors, rocket launchers, parts of atomic bombs, and electronic devices, as well as the ever-necessary guns with their mounts and fire-control equipment. Not all its activities center on war, however. Emergency jobs, like gear for lock gates at Panama Canal, are handled in stride. Also little things for the Government Printing Office, the Navy Medical Center, and even bench marks for the Coast and Geodetic Survey.

It will be apparent that the Naval Gun Factory provides opportunity for large numbers of mechanically minded young men and embryonic engineers to get experience such as they can hardly get elsewhere. Budding chemists and metallurgists also find an environment that challenges the best that they may be able to develop.

Policy — There are those who have expressed the belief that government plants operate to the disadvantage of industry. It might be well therefore to state briefly the policy of the Naval Gun Factory.

In the first place the Gun Factory is essentially a pioneering workshop. Here is developed a satisfactory way of making many complicated assemblies. When such development work is completed, manufacturing specifications can be drawn up and tenders called for from outside manufacturing plants. The idea is to feed this work to industry so that the Gun Factory can be free to turn to other developmental work. If industry cannot absorb all the work required — as happens during wartime — then the Gun Factory is ready to handle the excess.

Another set of circumstances may be considered where several outside firms are each

making different parts of one final assembly. If one of these firms runs into difficulty, then (to avoid delay to those producing other parts) the Gun Factory is ready to produce the items until such time as the trouble is overcome. Furthermore, experts from the Gun Factory are frequently sent to outside plants to render such assistance as may be needed.

In wartime, when replacements are generally both unexpected and urgent, the national plant is ready to fill the imperative need of the moment. In calling for tenders the government plant has to compete on a strictly price basis.

In these days when unions are so insistent on their privileges and the exact letter of their contracts, a word should be said here regarding the reaction of the civilians in the Government's employ to sudden demands requiring overtime work — sometimes straight through the week, including Sundays. The spirit of cooperation that is evidenced shows clearly that their country's need is their first consideration — and well it is that this is so. One is reminded of the words of Carlyle, "For work is the grand cure for all maladies and miseries that beset mankind — honest work that you intend getting done"; or those of Emerson when he says, "Then there are the working men on whom the burden of business falls — those who love work, and love to see it rightly done, who finish their task for its own sake; and the world is happy that has most of such finishers. . . . . Work is Victory; wherever Work is done, Victory is obtained."

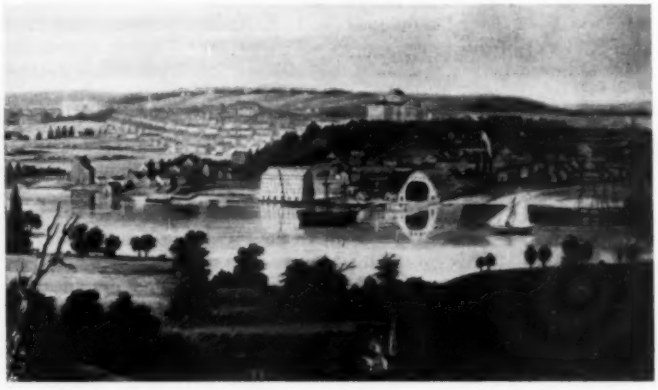


Fig. 1 — Reproduction of an Old Painting Showing the Washington Navy Yard in 1837, With the Partly Built Capitol on the Hill in the Background

NONFERROUS FOUNDRY OPERATIONS

The nonferrous foundry is housed in a building 296 ft. long by 117 ft. wide, with an average height of some 85 ft., and a maximum height to roof peak of over 100 ft. It is divided lengthwise into three bays. At one side, the narrowest bay (25 ft. wide) contains the molding machines, bench molders, and core room. The 54-ft. center bay is for medium and large floor molding, and the 38-ft. bay on the other side contains the melting department.

One's first impression of the bronze foundry is its spaciousness; the second is of good housekeeping. There is room for everything and everything is in its place. Much modernization has occurred since prewar years, when the writer visited the Washington Navy Yard. Labor-saving devices have enabled the regular work to be done quicker. Much more new work in wide variety can be handled and many more can work to advantage.

The metal used is mainly scrap returned in the form of obsolete or worn-out equipment. Such additions as may be required to maintain the correct composition are made in the form of virgin metal. New alloys, when required, are compounded from virgin metal. When one is told that as many as 20 alloys are sometimes melted in one day's operation, he gets an idea of the variety of activity and the complexity of the gun mounts, fire control, and other items under construction.

Long ago management of the foundry showed foresight in adopting silicon bronze as a useful alloy, and today many castings of this composition, both large and small, may be seen on the foundry floor. With the growing scarcity of tin it seems probable that ever-increasing quantities of it will be cast.

For fair-sized castings of thin wall, say 0.20 in., a modified gun metal (copper 88%, tin 8%, zinc 4%, deoxidized with phosphorus) is favored. Manganese bronze with strength of 100,000 psi., heat treated aluminum bronze, and aluminum alloys are also among those in regular use. The alloy that gives them the most trouble is 85/5/5/5 — and this confirms the writer's experience.

Most of the melting units are pit crucible furnaces fired with natural gas. The installation provides 38,000 lb. of bronze per 8-hr. shift. There is also an indirect arc rocking-type furnace of 1000-lb. capacity. All told, the melting room can turn out over 100,000 lb. of molten metal each 24 hr. The present production (about 20 tons daily) could be doubled and still leave a wide margin for shut-downs for repairs.

The sand used for bronze is Albany of a grade suitable to the job in hand. It is mechanically air conditioned, cleaned, watered to the required temper, and delivered to the machine molders via hoppers. Physical constants of the sand are laboratory controlled.

The temperature at which the metal is poured into molds is rigidly controlled by suitable pyrometers. (Cartridge cases are produced in an adjacent building, the metal being melted in Ajax-Wyatt induction furnaces.)

Journeymen molders are used on all machines. This has the advantage that if, at any time, more workmen are needed for the floor molding, they can be taken from the machines. Many young molders of high quality are available, and one hopes that department foremen will be drawn from these as they qualify and the need arises.

Nonferrous castings are cleaned by hydroblast, 1200-psi. pressure. This wet cleaning does away with the hazard of silicosis. An interesting item in the cleaning department was a 38-in. circular saw. It removes gates and risers to tolerances approaching that on a boring mill, and often is obviously more suitable.

Heat treatment for stress relief after rough machining is a common practice and has much to recommend it. The castings are heated in a suitable furnace at 900° F. for periods suited to their cross sections. A battery of large furnaces for this purpose is shown in Fig. 3. It is a pity that more foundries do not take the precaution of stress annealing bronze castings. It is the writer's opinion that, in time, such annealing will become the rule rather than the exception.

Patterns of the utmost complexity are everyday matters — in fact, nothing is too complicated for the efficient pattern makers. Likewise, an up-to-date core room, equipped for making ordinary cores on a production basis, as well as the most intricate cores for special jobs, is an indispensable adjunct.

REMARKS ON PRODUCTION

Some idea of the fineness of the work done in the Gun Factory's bronze foundry may be gained when one learns that the casting tolerance is of the order of 0.02 in. in a casting, say 21 in. in diameter, and that machining tolerances are frequently 0.0005 in.

One of the largest castings that has been made is a torpedo spoon requiring 18,000 lb. of molten manganese bronze. A gun director base called for 5000 lb. of aluminum alloy — which, in view of the lightness of the alloy, corresponds in volume to a bronze casting of 15,000 lb.

When one leaves the bronze foundry, and enters the machine shop where the guns and gun mounts are machined and assembled, one begins to realize how important is the bronze. The number of items in steel and nonferrous is about equal, while the tonnage ratio is about 30% by weight of nonferrous (most of which is bronze, the balance being aluminum alloys).

It is important that as much of a gun

Fig. 2 — Airplane View of U. S. Naval Gun Factory at Present

mount or a rocket launcher as practicable be nonsparking, and this is one of the reasons for the generous use of bronze. Another consideration calling for aluminum alloys is that the center of gravity of the ship and all upstanding gear should be as low as possible. For example, in a rocket launcher only the smaller part of the height is represented by the rockets and the carrier, but the base stands about 25 ft. high, giving a total height of some 35 ft., most of which is bronze with some aluminum alloy. As one stands on the machine shop floor and gazes upward to the towering structure, it becomes self-evident that the balance of the whole is a prime consideration. Here comes in the advantage of the light aluminum alloys. The ratio of weight to strength is of great importance here, as well as in aircraft.

The rocket launcher contains a particularly fine example of intricately cored aluminum alloy casting. The surface was very smooth, the fillets and corners clean and free from dross. The tolerance was 0.02 in. in the length of some 4 ft., and the weight was some 700 lb.

Even iron castings are sometimes made in the bronze foundry. (In such instances the iron is melted in the electric rocking furnace.) Not long ago over a million miniature cast iron bombs were required by the fleet air arm for target practice. No commercially produced molding machine was obtainable, so the Naval Gun Factory made its own. It worked smoothly and efficiently.

When the ordinary civilian speaks of guns he probably visualizes a cylindrical gun barrel placed on a trunnion, such as the Civil War relics mounted for decorative purposes in the public squares of Northern cities. Or perhaps he thinks of the small brass cannon he used as a boy (before safety-first Fourth of July's were enforced) to wake up the neighborhood. Brass guns have only historical interest now, of course. The Washington Navy Yard remembers, with pride, its work during the transition from the smooth bore to the rifled gun, from the muzzle loader to the breech loader, from the percussion cap to "quick-fire" electric detonators, from optical pointers to radar-controlled batteries. The civilian visitor at the Gun Factory today is struck by the massive and complicated structure of the gun mount and with the maze of wires leading to mysterious instruments. The modern gun has little in common with the old brass cannon!

The writer witnessed the firing of a 3-in., 50-caliber twin-mount anti-aircraft battery. Seventy-five shots a minute were fired from each of the barrels. Aside from the stream of fire which erupted, the electrical and electronic apparatus would fascinate anyone — and the visiting metallurgist was no exception.

The two days spent by the writer in the foundry and adjoining departments were an inspiration. Likewise, the visit was made a very pleasant experience by many courtesies extended by J. E. Crown, foundry superintendent, and Earl Bush, Admiral Hanlon's personal representative.

After such a tour an observer feels that certainly foundry work has much to recommend it to the young man of today. It is a basic industry and, as practiced under the conditions prevailing at the United States Naval Gun Factory, is a healthy and fascinating occupation, very different from the unpleasant surroundings in foundries of earlier days. Those so engaged can certainly feel that they are in the front line of their country's preparedness for defense.

Fig. 3 — Battery of Large Annealing and Stress Relieving Furnaces

Radio-Autographic Determination of Lead in Stainless

By Major L. R. Standifer
U.S.A.F., Graduate Student
and Mars G. Fontana
Professor and Chairman
Department of Metallurgy
Ohio State University

RADIO-AUTOGRAPHIC tracers have usually been limited to work in botany and biology, but can well be applied to the study of alloys if the constituent of interest is present in minor amounts and has a tendency toward preferential distribution. Basically, the technique is simple: A section containing the suspected radio-isotope is placed in contact with a photographic film, and the particles emitted will expose spots on the film which, after development, will be darkened. This picture of the tracer distribution is termed a radio-autograph.

These techniques were used to determine the distribution of small amounts of lead in a cast stainless alloy. Lead is apparently insoluble in these alloys, and is sometimes added to improve machinability. Our purpose was to determine the mode and distribution of segregation, if any exists — a problem not satisfactorily attacked by conventional metallographic techniques. It is hoped that a description of our methods may be of help to others contemplating metallurgical work with radioactive tracers.

Beta particles are better suited for radio-autographs than gamma rays, and are practically mandatory where high resolution is demanded. Various estimates have been made of the number of particles necessary to produce a satisfactory image. These vary from 10^6 to 10^9 beta particles per square centimeter of film.

Three factors limit the utility of this new method considerably: First, the radiation from a point is emitted in all directions; a sharp image is difficult to obtain with beta particles and practically impossible if energetic gamma radiation is present. Second, the amount of radio substance used must be small or all the complicated shielding and handling care of a "hot laboratory" must be employed. Third, the resulting film must be enlarged for study and the method is limited by the resolution (grain size) of the photographic emulsion.

Safety hazards are so numerous and varied (depending on the material used) that they will not be discussed in detail, but it is highly recommended that a good text such as "Radioactive Tracer Techniques" by George K. Schweitzer or Technical Report 5669 of the Department of the Air Force, Air Materiel Command ("Handbook of Radioactivity and Tracer Methodology") be studied carefully before starting any experiments. The extreme precautions and special equipment of "hot laboratories" are unnecessary for tracer experiments, wherein the level of radioactivity is very low — on the order of a few microcuries (10^{-6} curie). It is obviously desirable to keep activity in the tracer level if possible.

SELECTION OF ISOTOPE

In selection of the proper isotope of lead to be used in this study, the following were prime considerations:

1. The substance had to be primarily a beta emitter. While *very* thin layers of any metal will stop beta particles (particularly low energy betas), gamma radiation will penetrate metal a considerable distance and give a diffused picture. Beta emanations, almost exclusively from the prepared surface itself, allow fairly high resolution without the extensive shielding required by gamma emitters. Furthermore, the specimen may be handled with rubber gloves if the level of activity and energy of the beta particles are sufficiently low.

2. A fairly long half-life was necessary, since several hours are required for the entire experiment — melt to exposure of the film. Additional time is needed to prepare the isotope in its desired form and purity and for making trial exposures. Extremely long half-life, on the other hand, is undesirable, since semi-permanent activity presents additional health hazards and contamination problems.

3. Availability and cost of the isotope are also important. The U. S. Atomic Energy Commission and other vendors of radioactive isotopes furnish price lists on available material,

or the particular isotope may be artificially prepared by bombardment in a cyclotron. Cost of the latter is normally quite high and the products present several practical limitations, if quantitative work is anticipated.

Pb^{210} was chosen for this work. It has a half-life of 22 years, emitting a low-energy beta particle and a very weak gamma ray while passing to Bi^{210}. The daughter has a half-life of 5 days and emits an energetic beta particle and no gamma radiation. Table I gives the mode of decay. The energy quoted for the beta particles is the energy of the *most* energetic particle (high end of beta spectrum) and their average energy will be much lower.

Other possible lead isotopes were eliminated from consideration because of unsuitable radiation characteristics, too short half-life, or scarcity and cost.

J. D. Kurbatov of the department of physics, through a grant by the Development Fund of Ohio State University, obtained one millicurie of Pb^{210} (Radium D) as lead nitrate solution from Canadian Radium and Uranium Corp. of New York City. This quantity of radiation threw the experiment into the "intermediate level laboratory"; however, health hazards were not as bad as this would indicate because gamma radiation was of such low energy that ordinary glass was a sufficient shield. The lead nitrate solution had to be reduced to metal before alloying and, after alloying was completed, the metal sample itself effectively shielded radiation to a degree that the remainder escaping into the atmosphere was well within "tracer limits". Only the lead atoms exposed on the surface of the metal were able to expose the photographic plate; most of the large amount of activity was locked within the sample itself.

Table I* — Radioactive Decay of Pb^{210}

Pb^{210} (Radium D)
Half-life, 22 yr.
Beta, 0.027 mev. (million electron-volts)
Gamma, 0.007 to 0.04 mev.

Bi^{210} (Radium E)	
Half-life, 5 days	Long half-life
Beta, 1.17 mev.	Alpha, 5.02 mev.
No gamma	
Po^{210} (Radium F)	Ti^{206} (Radium E)
Half-life, 138 days	Half-life, 4.23 min.
Alpha, 5.30 mev.	Beta, 1.7 mev.
Gamma, 0.084 mev.	No gamma
Pb^{206} (stable)	Pb^{206} (stable)

*From Air Force "Handbook of Radioactivity and Tracer Methodology"

EXPERIMENTAL PROCEDURE

It should be emphasized that all experimental procedure should be performed several times using inactive materials until every detail has been worked out completely. Every step must be thoroughly rehearsed in order to avoid failure with attendant loss of expensive material. In addition, "dry runs" help to eliminate unforeseen health hazards and laboratory contamination. This is more important than it might seem, for a laboratory once contaminated with a substance of long half-life (such as Radium D) is quite useless for further experimentation with radioactivity, and even for conventional use if this contamination is severe and cannot be removed. All procedures involving heat were enclosed or performed under a suitable hood, as sublimation of the radioactive material presented a serious possibility for contamination.

Preparation of Metallic Lead — The radioactive lead nitrate was mixed with ordinary lead nitrate, evaporated to dryness, broken down to lead oxide, and then reduced with hydrogen to metal in a porcelain boat and atmosphere of hydrogen. Lead nitrate decomposes at 880° F. (470° C.), going first to one of the lead oxides. There is a considerable evolution of gas at this stage and the material passes through a liquid phase. It was first feared that a ceramic would react during the process and a great deal of the lead would be lost. Accordingly, both iron and nickel crucibles were tried (using ordinary lead), without success. The lead immediately formed a high melting scum (probably with the surface oxides) and could not be removed without considerable loss. Apparently the temperature was not high enough for reaction with the ceramic boats, since very good recovery was obtained.

After the diluted radioactive lead nitrate was evaporated to dryness under a heat lamp the dry powder was transferred to the porcelain boat. The boat was then placed in a reduction tube (a length of 3-in. Pyrex tubing) and tightly stoppered. This part of the procedure was the most critical from the standpoint of radiation. All equipment was handled by tongs, and rubber surgical gloves were worn for additional protection. Glass was kept between the operator and the material and thick lens glasses were also worn to protect the eyes from any possibility of accidental "beta-burn".

The tube was swept out with nitrogen before the hydrogen was introduced. As the

hydrogen left the discharge tube it was ignited under a hood. The flame insured an adequate supply of hydrogen for reduction.

When the flow of hydrogen had been established at a steady rate, a flame from a wingtop-type burner was placed under the reduction tube, heating it very carefully, since the nitrate may decompose quite violently and material be lost by splattering. Once the initial decomposition reaction is completed, the temperature is raised slightly and the reddish-yellow oxide changes to a red color, then gradually to the gray of pure lead. Droplets of lead collect in the bottom of the boat at just under red heat. Finally, the hydrogen is swept out of the tube with nitrogen and the boat removed. To facilitate handling, the lead was again melted, collected into one large drop and cast into a clean boat from which it was readily removed.

Melting and Alloying — The cast stainless alloy used in this experiment was "Durimet 20" kindly provided by the Duriron Co. which has a nominal composition of 29% nickel, 20% chromium, 1.75% min. molybdenum, 3.5% copper, 1.0% silicon, 0.07% max. carbon, remainder iron. 0.04% lead was to be added to this alloy, a value well above the solid solubility limit and which should give a representative picture of the distribution at low concentration.

Before actual melts using radioactive materials could be made, it was necessary to determine if the lead would be evenly distributed throughout the ingot with our technique. Several melts with different amounts of lead added were therefore made, and were then analyzed in the Duriron Co.'s laboratory. When 0.04% Pb was added the ingot analyzed 0.039% at the top and 0.035% lead at the bottom. When 0.08% Pb was added, the ingot showed the following: Top 0.077%, center 0.071%, and bottom 0.065%. This shows fairly good distribution, and also little loss of lead.

Figure 1 is a drawing of the principal components. The small induction furnace contains a fireclay crucible 1 in. inside diameter and 3 in. long. The copper coils are water cooled and insulated from the crucible by a layer of mica and a layer of magnesia powder. A new crucible was used for each melt because the metal solidified in place.

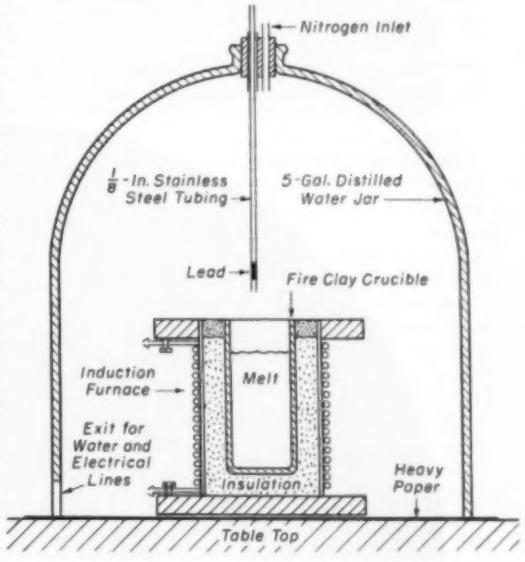
Several trial melts were made before a good method was devised to introduce the lead without excessive loss. The alloy was above 2650° F., its melting point, due to a certain amount of superheat, and lead boils at 2950° F. We finally inserted the lead into the end of a ⅛-in. tube of 18-8 stainless steel. Its entire end was plunged into the molten alloy and a stirring action continued until the submerged section of the tube had melted away.

A glass "hood" was constructed from a 5-gal. distilled water jar as shown in Fig. 1. A hole was cut in the side for access of electrical and water lines. The cork stopper contained two glass-lined holes, one to carry the steel stirring rod and one to admit nitrogen. The entire assembly rested on thick wrapping paper, later to be discarded. This equipment effectively prevented laboratory contamination by radioactive lead.

In the radioactive melt, 0.0655 g. of lead was added to 144 g. of molten Durimet to give an alloy of 0.0455% lead. Based upon the results of the preliminary experiments, a section one third the length of the ingot from the bottom should contain about 0.04% lead.

A prior study of the solidification habits of the alloy determined the cooling conditions necessary to obtain satisfactory grain size. Slowly reducing the power supply during solidification resulted in large, well-defined, "gross" grains which contained a continuous network of small dendrites. Solidification with the power off reduced the grain size slightly but did not appear to affect the dendrite size within the gross grains. Power-off solidification was used with the radioactive melt.

Fig. 1 — Equipment for Melting Stainless Steel and Alloying It With Radioactive Lead



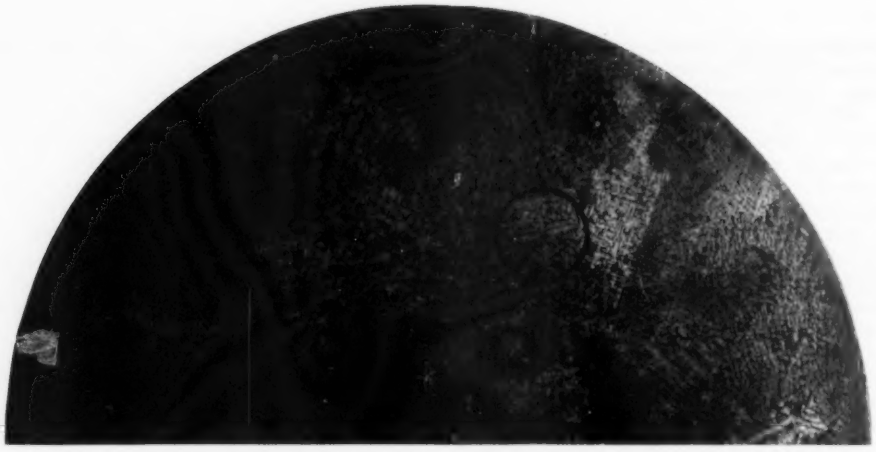


Fig. 2 — Macrograph of Etched Cross Section of 1-In. Ingot; Oblique Illumination; 6.5×

Preparation of Radio-Autograph — Crucible and ingot were removed from the furnace and the crucible cracked away. The ingot was placed in a vise and sawed in two, one third of its length from the bottom, giving a cross section about 1 in. in diameter. The saw marks were removed from this surface by hand grinding on two grades of rough emery paper (No. 200 and No. 50). Next the surface was prepared for exposure to the photographic film by successive polishing on 0, 00, and 000 emery paper. All polishing operations were conducted under water to prevent scattering of radioactive dust; wheels would have been rendered useless for further service by contamination.

The sample necessarily had to be handled with rubber surgical gloves. To avoid rubbing the gloves on the emery paper, specimens were held well above the surface being polished. It was therefore extremely difficult to obtain a flat surface, necessary for close contact with the photographic emulsion. In fact, for this reason glass supported photographic emulsions were unsatisfactory.

Since the distribution of lead in the alloy could not be foretold, several exposure periods of 3, 12, 24 and 72 hr. were tried. The unetched specimen was taped to the film with the prepared surface and the emulsion in direct contact. It was found that direct contact of the specimen with film-backed emulsion over a 24-hr. period gave the best definition for this particular concentration and distribution of radioactive lead. A sponge, back of the film and taped to the assembly, pressed the film to the metal and thus maintained intimate contact. Generally, X-ray films are used, but there are now on the

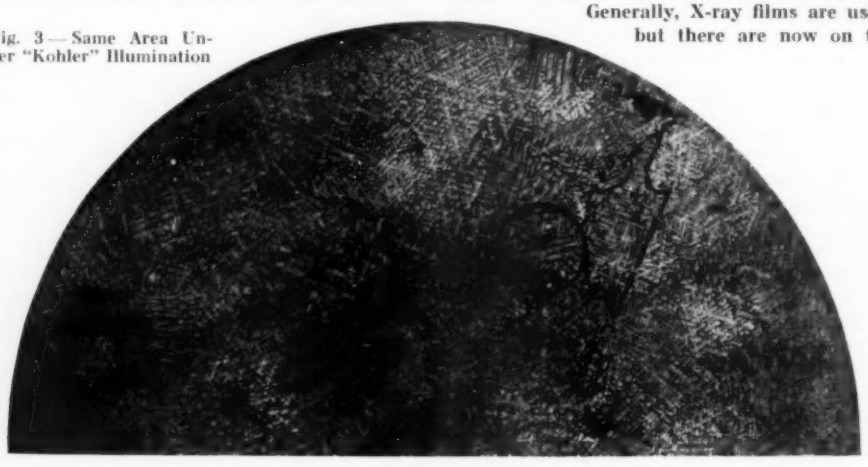


Fig. 3 — Same Area Under "Kohler" Illumination

market specially prepared photographic emulsions for practically any need. "Eastman Spectrographic No. 1 Emulsion" was used in this investigation, since the radioactivity was fairly high and the emulsion is fine grained, giving fairly good contrast and resolution.

Some experimenters deposit a very thin (wet) emulsion film directly on the prepared sample surface and strip it after exposure. This should give very high resolution and make identification of the areas easier, but it is hard to manipulate.

Enlarged prints of the radio-autographs, magnified 8 times, were made for study. Photomicrographs were also used to compare the actual structure with the distribution of lead as shown by the radio-autograph These were taken by oblique illumination and also by "Kohler" illumination described by George L. Kehl in his "Metallographic Laboratory Practice". Prior to photographing, the specimen was etched 45 to 60 sec. in a mixture of 40 ml. HNO_3, 10 ml. HCl and 1 g. of $FeCl_3$. This reagent attacks the Durimet alloy very rapidly and care must be taken not to overetch.

Fig. 4 — Print From Radio-Autograph of Unetched Section, Enlarged 6.5×

Results and Discussion — From a consideration of the solubility of lead in the individual metals constituting Durimet 20 it would be expected that lead would be practically insoluble in the solid alloy. Since Durimet 20 is presumably a single-phase alloy, it was assumed at the beginning of this investigation that lead in excess of the solid solubility limit would be segregated at the grain boundaries.

The micrographs and the radio-autograph cover identical areas and have identifying features that are marked (circle and arrow). Particles of radioactive lead darken the radio-autograph and therefore print as light spots.

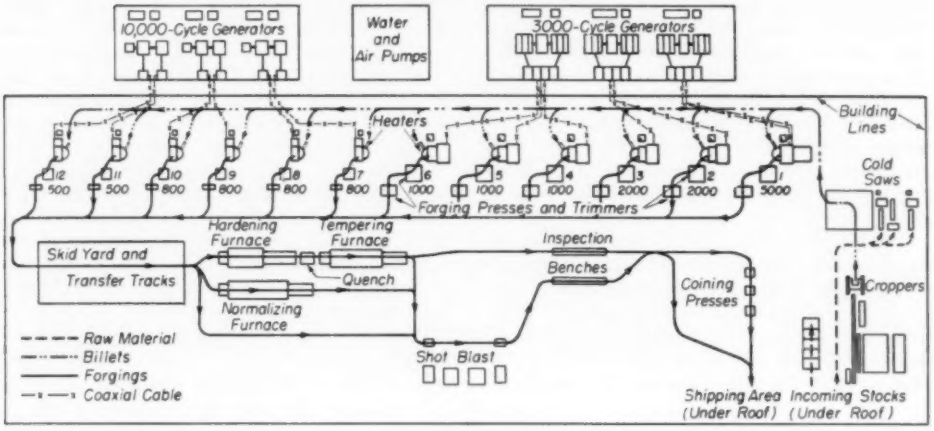
Dendrite cores show up as dark lines on the radio-autograph print and are therefore relatively lead-free. Light spots (locations of lead concentrations) appear evenly distributed at locations corresponding to the interstices of the relatively lead-free dendrite cores.

The radio-autograph indicates that the lead is trapped between the branches of the small dendrites within the gross grains. There appears to be little evidence of preferential segregation of the lead at the grain boundaries in excess of that found between the dendrite branches within the grains.

In the upper right portion of Fig. 2 is a light, well-defined grain (adjacent to the reference circle) which is outlined by black dots in Fig. 3. Reference to Fig. 4 does not reveal preferential segregation of lead at the boundary of the grain, although the orientation of the dendritic structure within the grain is clearly defined. Several well-defined grain boundaries are apparent in the upper left portion of Fig. 3. These boundary areas can be identified on the radio-autograph (Fig. 4) by dendrite orientation, but do not show any surplus precipitation of lead in preference to other locations within the grain. Some segregated lead — apparently an average amount — is present at the grain boundaries.

It is concluded that lead does not segregate preferentially at the grain boundaries in cast Durimet 20 alloy containing 0.04% lead to a greater extent than is manifested by the segregation of lead between the dendrite branches within the grains.

Fig. 1 — Schematic Layout of Modern Forge Plant at Bromsgrove, England, Using High-Frequency Current as Heating Medium



High-Frequency Heating of Forging Billets

HEATING OF FORGING BILLETS by high-frequency electrical currents is not an especially new idea. There is no progressive forge shop which has not considered it carefully, or even installed coils alongside certain presses or hammers and used them in production. Two or three important shops, new or revamped, rely completely on this mode of heating. However, the English works of John Garrington & Sons Ltd., in Bromsgrove, deserves special attention because it utilizes a new design of heater, and furthermore because of its size and the diversity of product, and because of the unusually fine working conditions and labor-saving arrangements.

Unusual equipment installed alongside American presses in new British forge plant

With only 12 forging units, this department can produce 20,000 tons of steel forgings per year. This is about 25% of Garrington's post-war capacity, which, in turn, approaches half that of the whole British prewar forging industry. The electrical heating equipment, supplied jointly by Birlec Ltd. and the Electric Furnace Co., serves the latest types of American forging presses of various sizes, ranging from two 500-ton units to a giant Maxipres of 5000 tons capacity (one of the world's largest). Each press has its own stripping or trimming press alongside, whose capacities range from 75 to 600 tons.

Heating periods are cut drastically from those required by conventional methods. For example, a 1¼-in. square billet is heated to forging temperature in 45 sec. instead of the 10 min. required in an oil-fired slot furnace; a 4-in. billet in 7 min. instead of 20. The shorter heating times reduce scale formation on the billets and so facilitate the production of forgings with a good surface finish.

The general flowsheet for steel bars, cut billets, and forgings is shown in Fig. 1. The 12 presses are in one line occupying the whole length of one 550-ft. bay. Arranged in order of size, each is grouped with its own high-frequency induction heater and trimming press.

This new £1,000,000 forge at Bromsgrove is set out as tidily as an exhibition hall. The main building, comprising three bays 550 ft. long for forging, heat treating, and finishing, respectively,

with a 420-ft. by 70-ft. transverse bay for steel stores and shipping platforms, covers an area of 3½ acres, and is a completely steel-framed building having a roof of Ruberoid insulated steel deck. The building has been designed to give maximum benefit from natural lighting through vertical glazed exteriors. About a quarter of this area is prepared as movable frames, electrically operated. Each side of the building is glazed completely from the eaves down to a point about 10 ft. above ground level.

Details of the electrical equipment have been published in *Electrical Times* (London), March 9, 1950. As can be seen from Fig. 1 and the schedule of main equipment, two frequencies are in use, namely, 3000 and 10,000 cycles per sec., for large (2 to 5 in.) and small (1 to 2 in.) billets respectively.

The 10,000-cycle generator house contains three generator sets made by British Thomson-Houston Co. Ltd., each consisting of a 400-volt, 550-hp. induction motor, driving two 150-kw. alternators, each of these in turn generating at 500 volts, single phase. The 3000-cycle current is supplied by three 1200-hp. motor-generator sets made by Metropolitan-Vickers Electrical Co. Ltd. Each of these motors is likewise mounted between two alternators which are themselves homopolar-type inductor generators. These alternators each have two 250-kw., 1400-volt windings, which can either be coupled or drawn from independently, thus giving various outputs required for the individual heaters according to size and capacity. Auxiliary equipment in each house, besides necessary control panels for incoming power, include condensers and automatic controls to maintain the output voltage at the predetermined point. Both of the generator houses are completely air conditioned.

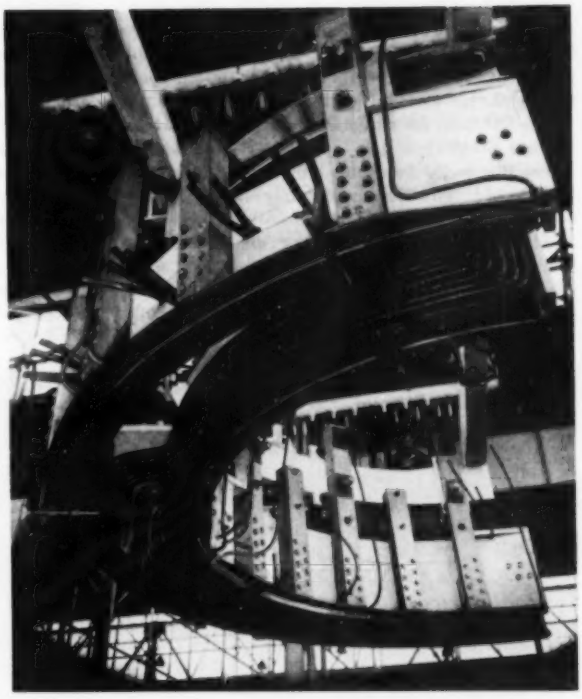


Fig. 2 — Semicircular Channel, Viewed From Below, Lined With Insulated Copper Pipes (Water Cooled) Forming Conductors for High-Frequency Heating Currents

Coaxial cables carry the current to the heaters. The necessary information for the operator is given on cards which detail the coils to be used for a particular job, the voltage, power, billets per hour, and the settings for the adjoining capacitors.

At the side of each press stands a heater

Schedule of Main Equipment

Press			Billet Section	Heater		
Number (Fig. 1)	Kind	Tons Capacity		Hearth Diameter	Rating	Output per Hr.
1	No. 7½ Maxipres	5000	4½ to 5 in.	7 ft. 6 in.	800 kw.	4800 lb.
2	No. 6 Maxipres	2000	2¾ to 4 in.	5 ft. 6 in.	400	2400
3	20C Ajax	2000				
4, 5, 6	No. 4 Maxipres	1000	1¾ to 2½ in.	5 ft. 6 in.	250	1500
7, 8, 9, 10	No. 3 Maxipres	800			300	1800
11, 12	5C Ajax	500	1 to 2 in.	4 ft. 6 in.	150	900

station, comprising a control cubicle, a capacitor enclosure, and the inductor coil and rotary hearth. The rotary hearth, a British development, is used in conjunction with a channel-type coil, shown in Fig. 2, which permits the billets to travel on a turntable closing its bottom so that no part of the electrical conductors is *below* the metal being heated. This minimizes the chance that iron oxide may lodge on the conductors or their insulation, flux therewith and destroy their operating characteristics. Since previously used induction heaters ordinarily consist of a coil completely surrounding the billet, it was practically impossible to arrange matters so there would be *no* contact between coil insulation and hot iron oxide.

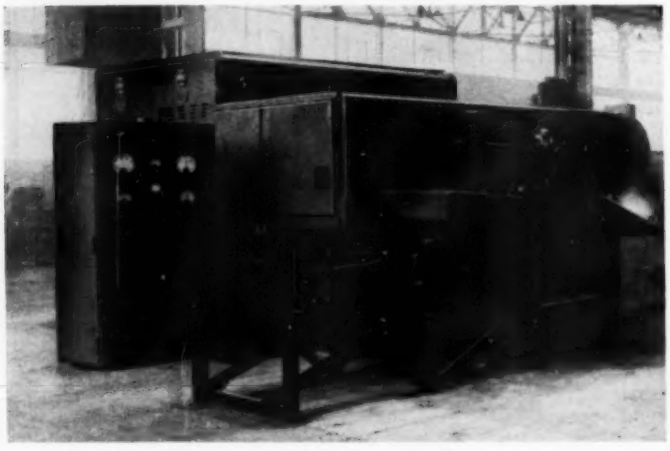


Fig. 3 — Largest of the Heaters, 7 Ft. 6 In. Hearth Diameter. Control cabinet at extreme left; capacitors in two banks at rear, heater in front, inclined platform for billet supply in immediate foreground. Operator is at loading station. About one quarter of turntable is exposed; rear half of it is below heating coils; in the final quadrant the hot blank is in a muff, prior to automatic ejection down chute to level of bottom die of adjoining trimmer press

Obviously, the use of a circular hearth with close clearances between inductor and billet limits sharply the billet lengths. The metal used in Garrington's new plant is cut into short, blocky pieces, suitable for press forging. Billets can therefore be placed end to end on the turntable at the loading station, where proper stops and guides aid the operator in locating each piece accurately. The turntable advances slowly and continuously, properly adjusted by speed reducers so the billets are thoroughly heated by the time they have passed through the semi-circular channel. At the discharge end they run into a heat-insulated muff, where they remain until they are well clear of the coil. A trip lever then lifts the last section of the muff, operates a knock-off gear which pushes the hot billet off the table and down a chute to the press operator (Fig. 3). Ejection is automatic when the front end of the hot slug reaches the trip lever.

The inductor coils are copper pipe and are water cooled. They are also provided with a refractory lining and covering which is a good heat insulator and is not readily fluxed by iron oxide. The mechanically strong hearth refractory is roughened and also a poor conductor of heat so it won't chill the bottom surface of the heated piece. Coil construction is illustrated in Fig. 2. Similar coils are provided in a variety of sizes, corresponding to the various sizes (cross sections) of the billets being forged. Close coupling between coil and billet is, of course, an important factor in economic working. Efficiencies between 390 and 450 kw-hr. per ton of billets are achieved, and Garrington's have stated that over-all costs are lower, even with a high rate of close to 1¢ per kw-hr., than in their other plants which use oil fuel for heating.

Once the electrical heating equipment has been started up, the operator has only to lift the billets from the charge pallet and place them on the turntable. The pressman has to transfer the hot billet from the chute to the die and operate the press. No walking is necessary. Similarly, a chute delivers the pressing to the trimmer. No operator's job is arduous nor calls for a high degree of skill. In this mode of working, the induction heater rather than the forge operator sets the speed of working — and the higher production is achieved with less manual effort.

The coils used in the heaters are readily accessible for purposes of maintenance. The underside is open to allow passage of the refractory hearth, while the top is covered tightly by refractory tiles to prevent undue heat loss and air infiltration. If necessary, any of these tiles may be lifted aside to remove a troublesome billet within the coil. (The drive mechanism

on the turntable stalls if it is overloaded beyond a small margin.) The supporting framework is designed to allow the whole coil assembly to be changed when billets of a different size are to be heated. Coils have been changed in as little as 10 min., but the average time is half an hour, which is less than that required for changing the dies of the press. Spare coils are also stored for emergency use.

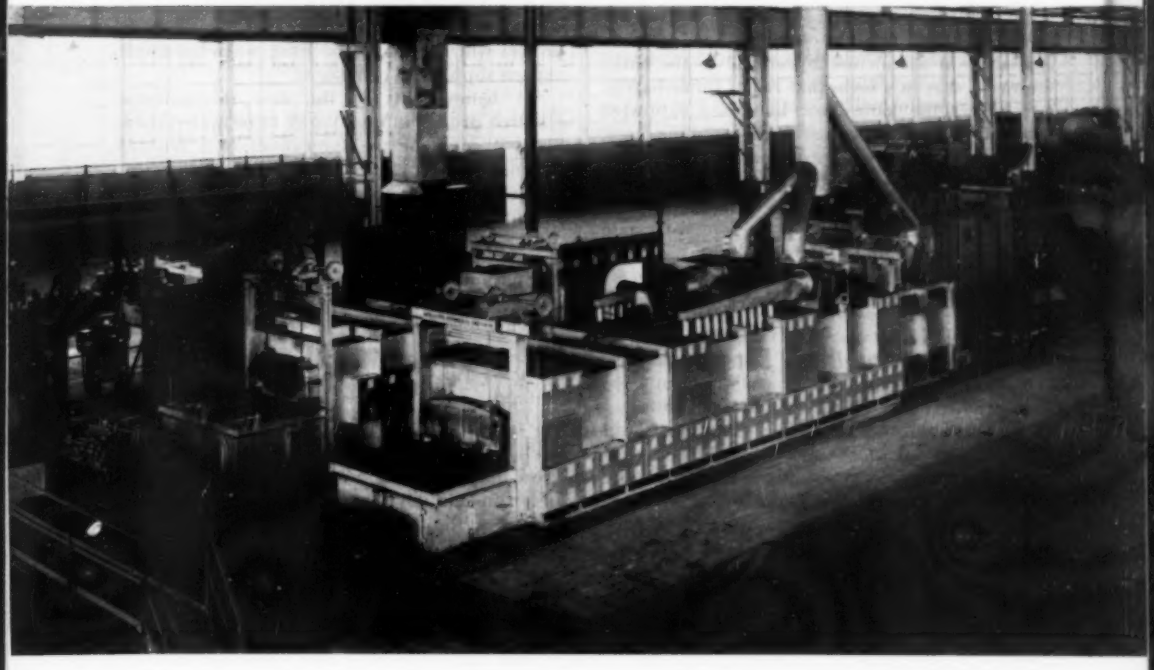
The heat treating equipment for completed forgings comprises three continuous electric furnaces (Fig. 4), one for hardening, one for tempering, and the third for normalizing. All three furnaces were supplied by Metalectric Furnaces Ltd., and are arranged for automatic temperature control.

Forgings to be treated are loaded on a link conveyer forming the traveling hearth of the hardening furnace; at the discharge end they drop into the quenching tank without being exposed to the atmosphere. A mesh-type belt conveyer lifts the work from the tank and carries it to the charging end of the tempering furnace, which is fitted with overhead fans for circulating the atmosphere, and which is designed so that it may be used as a supplementary normalizing furnace.

The normalizing furnace has the same type of conveyer (made of cast links of heat resisting alloy) as the hardening and tempering furnaces, the design being such that a flat hearth is provided on which both large and small forgings may be loaded directly. The complete furnace plant has a total connected rating of 1300 kw.

Conclusion — A great advantage of this induction method of billet heating is that forging can be commenced within a few minutes of starting up. A long period of preheating, as is essential with fuel-fired furnaces, is unnecessary. Stopping, followed by easy starting, for die trouble, meals, end of production run, is easily accomplished. The over-all cost is less than when using oil-fired furnaces. Finally, the cleanliness of the shop is impressive, and inducive to easy labor recruitment. A high rate of output is possible. High production means good wages for the semiskilled workers. With these benefits, labor problems are few.

Fig. 4 — Electrified Heat Treating Department, Photographed Prior to Installation of Presses in Bay Immediately at Rear. Normalizing furnace in foreground. Alongside is hardening furnace and (in line) the tempering furnace; between is a quench tank (concealed). End of skid yard and transfer tracks at extreme left



Correspondence

Removing Carbonate From Cyanide Plating Solutions

COLUMBUS, OHIO

The International Acetylene Assoc. has questioned the safety of my recommendation in "Bits and Pieces", *Metal Progress* for November 1948, that undesirable carbonate be removed from copper cyanide plating solutions by slow addition of calcium carbide (and proper venting of the liberated acetylene), with the suggestion that slaked lime be used instead.

The addition of calcium carbide to an aqueous solution in an open tank is definitely hazardous. I recommended small additions of calcium carbide *over a long period of time*, so that the acetylene never becomes concentrated enough to form an explosive mixture with air and can be removed safely by an exhaust system. This proposed method has the most practical value in controlling new solutions. In my original article I should have emphasized more clearly the necessity of avoiding any mixture of even small amounts of acetylene and air.

The use of calcium carbide is equivalent to an addition of calcium hydroxide to the bath; however, it is in a form that reacts immediately, preventing the bath from becoming saturated with hydroxide. Purified hydrated lime may, however, be used with excellent results in the precipitation of carbonates.

My article in the July 1949 issue of *Metal Finishing* gives further details on carbonate removal from cyanide plating solutions.

HARRY F. ROSS
Battelle Memorial Institute

Oxygen for Blast Furnaces

QUEBEC, CANADA

In his interesting article "Ten Years in Steel" published in the January 1951 issue of *Metal Progress*, Harry W. McQuaid makes the following statement: "The use of oxygen-enriched blast was hailed as a revolutionary possibility in cutting iron costs but *this seems to have reached a state of extreme quiescence*". The italicized part of this statement is mine, and refers to conditions that are quite true as far as the United States is concerned and he had, no doubt, American conditions in mind. However, the situation is very different in other steel-producing countries.

Two 100-ton, low-shaft oxygen furnaces are at this very moment being erected, one at Oberhausen, Germany, and the other at Ougrée, Belgium, under the sponsorship of the oxygen commission of the Office of European Economic Cooperation. [The O.E.E.C. is a committee of men with general offices in Paris representing the European governments receiving Marshall-Plan aid.] An interesting research program to be conducted at those two places has been drawn up and eight countries have already agreed to bear their share of the cost, while others are studying the advisability of doing the same thing.

Several American steel firms have been invited to join in the program but have declined.

The research will be directed by a committee of experts chosen by the participating countries, and the pooling of scientific knowledge and technical experience which this will bring about greatly enhances the chances of success. On the financial side, the cost to each participating country will be comparatively low, keeping in mind the scope of the program.

The German project at Oberhausen is in a more advanced state, and some results of tests should be available in the fall. The Belgian project will not start until 1952, when an ample oxygen supply can be insured.

I believe this is the first international research project in metallurgy to be undertaken. Since it could be the forerunner of a fruitful international collaboration in metallurgical research in years to come, it should be worth watching closely.

G. LETENDRE
Director
Dept. of Mines and Metallurgy
Laval University

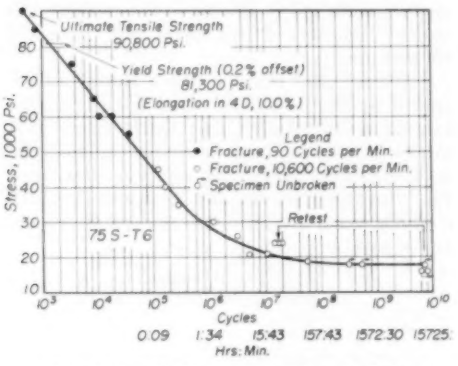
When Will It Fail?

DAYTON, OHIO

Despite the fact that, as is well known, steels have a definite fatigue limit (maximum stress that test pieces will endure without failure for an indefinitely large number of cycles) the present writer believes that the fatigue limits (in that sense) of aluminum alloys have never been determined. This results that "fatigue limits" for aluminum are generally based on tests to 500,000,000 (5×10^8) cycles. The words "fatigue limits" are in quotation marks, despite

the fact that the term corresponds to the definition in "ASM Metals Handbook", 1948 edition, p. 6: "The maximum stress that a metal will withstand without failure for a specified large number of cycles of stress. Usually synonymous with *endurance limit*."

In order to determine whether the "fatigue limit" so determined is the actual value for aluminum alloys, tests to about ten times as many cycles were made on polished cylindrical specimens of extruded 75S-T6 in the Materials Laboratory, Wright-Patterson Air Force Base.



Complete S-N Diagram Showing Definite Fatigue Limit for Aluminum Alloy 75S-T6. The stress corresponding to the horizontal part of the curve, in this diagram 5×10^8 cycles, establishes the "endurance limit"

Three specimens were run in the R. R. Moore machine at a speed of 10,600 r.p.m. at stresses of 18,000, 16,000 and 16,000 psi. for 7,200,000,000, 6,200,000,000 and 8,300,000,000 cycles respectively without failure. Even at this high speed the tests took about 18 months.

They were then retested to failure at a higher stress with the load being stepped up to 24,000 psi. without stopping the machine. The retest data plotted in the accompanying S-N diagram indicate that the previous long-time run did not injure the material. The surface on the gage section of the specimens was examined after failure, but no pits were noted.

The S-N diagram indicates that the fatigue limit for this particular alloy may actually be based on 500 million cycles. This diagram is also of interest in that it covers the range from 450 to 8,300,000,000 cycles (high to low stresses).

T. T. Oberg
Chief, Fatigue and Vibration Unit
Structural & Mechanical Test Branch
Materials Laboratory, Engineering Division
Wright-Patterson Air Force Base

Bonding of Titanium Carbide

Latrobe, Pa.

We have read with interest the report on the "Bonding of Titanium Carbide With Metal" by Walter J. Engel in the May 1951 issue of *Metal Progress*. These materials have excellent properties and are certainly of interest for high-temperature applications. However, we do not believe that the proper conclusion was drawn, nor did the report take account of other work with these materials.

The author's final conclusion is that "nickel, cobalt, and possibly chromium appear to have some promise as binder materials for sintered titanium carbide bodies". They certainly do; in fact, they make excellent binders for titanium carbide bodies! Our company has been making such compositions and has had them available for test and commercial uses since 1947. *Metals Transactions* for December 1949 ("Cemented Titanium Carbide", by John C. Redmond and E. N. Smith) describes our preliminary work on such compositions, now marketed under the trade name "Kentanium".

Thus, the work reported in Mr. Engel's article is in the nature of confirmation. It shows something of the sound nature of the bonding mechanism. It would appear that the author's conclusion should have been that their work *confirmed* the fact that nickel, cobalt and possibly chromium make good binders for titanium carbide bodies. It might also have been well to add the conclusion that other metals did not show promise as binders.

John C. Redmond
Vice-President, Kennametal, Inc.

Metallurgy in Spain

Madrid, Spain

Let me comment on the letter from Prof. F. R. Morral in *Metal Progress* for August 1950, wherein he gives an incomplete view of our metallurgy in Spain. He mentions only one integrated steel plant, the one located at Santander, yet it is quite evident that our 1949 output of 730,000 tons could not be obtained from this interesting and complete plant.

Our most important iron and steel integrated plants are those owned by the two firms Altos Hornos de Vizcaya and Duro-Felguera. The first has two works, one at Bilbao (Vizcaya) and another at Sagunto (Valencia) with capacities of about 500,000 and 200,000 tons. The works at Bilbao comprises six 400-ton blast fur-

naces, a bessemer plant with four 17-ton converters, an openhearth plant with four 80-ton furnaces, and another openhearth plant with five 30-ton furnaces. The one at Sagunto has two 400-ton blast furnaces, and an openhearth plant with four 72-ton furnaces and one 80-ton.

The other integrated iron and steel plant (Duro-Felguera) is at Asturias, with capacity of 150,000 tons of steel per annum, has three blast furnaces of 330, 130 and 100 tons per day, an openhearth plant with three 40-ton furnaces and one of 75 tons. All are equipped with adequate coke oven batteries and rolling mills for the production of structural sections, railway material, merchant bars, shipbuilding plates, boilers, sheets and tin-plate.

We also have several important works for making pipe, steam boilers, steam or electric locomotives, Diesel or electric engines, and ships.

The present *capacity* of the Spanish iron and steel industry is approximately 1,200,000 tons of steel per year. The maximum yearly *output* was obtained in 1929, over 1,000,000 tons. Professor Morral mentions the political and international maladjustments that have militated against the normal industrial activities in Spain since 1930. Another prime cause of a low operating rate is metallurgical, and relates to the high proportion of openhearth furnaces in our refining departments. Great difficulties have to be overcome — sometimes after a great struggle — to obtain the proper scrap supplies. Due to it, our output reached a maximum of only 800,000 tons in 1940, and has moved between 650,000 and 750,000 tons after that date. This is insufficient to cover our national requirements and the want of iron and steel products is strongly felt. For that reason, construction of a new integrated steel plant based on iron from ore is shortly to be started. The annual capacity of this plant will be about 600,000 tons.

We are glad that Professor Morral discovered a healthy and progressive body of metallurgists in our country, and that he found good things to say about the newly-formed Instituto del Hierro y del Acero (Iron and Steel Institute). The Institute has already undertaken much research work, in addition to the activities mentioned by him.

AGUSTIN PLANA
Director
Instituto del Hierro y del Acero

Strain Rate Sensitivity of Molybdenum at Room Temperature

By Robert Maddin and Robert Pond
Assistant Professors of Metallurgy
Johns Hopkins University
Baltimore

LITTLE or no data are available concerning the effect of strain rate on the plastic properties of pure molybdenum. In view of the potentialities for molybdenum, it seemed advisable to investigate the effect of strain rate on the elongation, reduction of area, tensile strength, yield strength and rupture strength.*

With regard to metals in general, it is known that extremely large changes in strain rate are necessary to induce even small changes in the stress-strain curves. However, it is very difficult to cover a very large range of strain rates, and thus definite quantitative conclusions regarding the strain rate effect have been absent. There is a limit to the maximum strain rate at which a specimen may be deformed (this was investigated by J. H. Hollomon and C. Zener and reported in the American Society for Metals *Transactions*, Vol. 32, 1944) and consequently the data obtained from tests at very high rates of strain must be carefully analyzed.

Climax Molybdenum Co. hot rolled $\frac{5}{8}$-in. rods were machined into 5-in. specimens with a gage section $2\frac{3}{4}$ in. long by $\frac{3}{8}$ in. in diameter. The test pieces were annealed for 1 hr. at 900° C. in an atmosphere of pure helium. Metallographic examination of representative samples

*This work was sponsored by the Office of Naval Research under Contract No. ONR 031-339.

indicated that about 5% of the material had recrystallized following this treatment.

These specimens were loaded at various strain rates and data taken as to the instantaneous diameter, strain in 2-in. gage length, load, and strain rate determined at time intervals one-thousandth of a second.

In order to accomplish definite and controlled strain rates, a Tinius Olsen, 50,000-lb., beam-type machine was used. This machine develops various crosshead speeds, depending on the intermediate gear train used. With any given gear train, the crosshead speed should be constant, providing the speed of the driving motor is constant. Variable resistance in series with the field of the motor provides a method of controlling the motor speed. A generator-voltage-type tachometer was attached to the motor. When the voltage of the tachometer was held constant by manipulation of the variable field resistance, the speed of the crosshead was also held constant.

The crosshead speed was measured by means of dial gages; readings were taken at definite time intervals. The strain rate was calculated by dividing the crosshead speed by the specimen length from shoulder to shoulder. Longitudinal deformation was measured by means of a Metzger extensometer up to a deformation of 0.03 in. per in. beyond which dividers and scale were used.

The instantaneous diameter was measured by means of a transverse clip gage which was made of phosphor-bronze strip onto which were attached two SR-4 strain gages. The clip gage was capable of following a reduction in diameter from ⅜ to ⅛ in., providing the reduction was uniform over the width of the gage. Time measurements were made by means of a stop watch. The strain rates used together with the ratio of highest to lowest rates are shown in the accompanying table.

RESULTS

The results obtained for specimens C-5 through C-10 are shown in the table and are plotted in Fig. 1. These specimens were annealed at 900° C. in a stream of pure helium for 1 hr. Specimens C-1 through C-4 were extended in the "as-received" condition. No grain size could be determined for these latter specimens. Their longitudinal section exhibited long fibrous grains. Despite the large amount of strain present in specimens C-1 through C-4 as judged by the condition of the grains, no large difference in elongation or reduction of area can be noted from the annealed specimens.

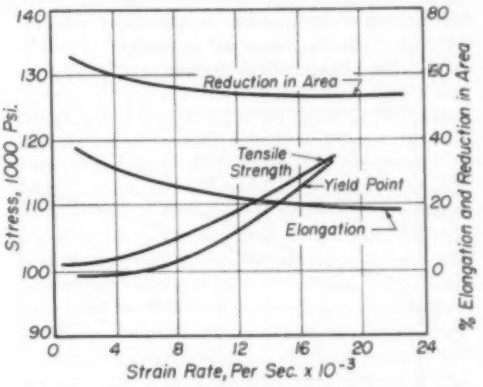


Fig. 1 — Strain Rate Effect Determined for Specimens C-5 Through C-10. These were annealed for 1 hr. at 900 °C. in an atmosphere of pure helium

As may be noted from Fig. 1 and the table,

Specimen	Tensile Strength	Yield Point	Rupture Stress	% Elong.	Reduction of Area, %	Strain Rate*	Ratio of Highest to Lowest Rate	Remarks
C- 5	101,500	99,000	198,280	36	65.4	0.18	1	Note (a)†
C- 7	104,200	101,000	182,700	24.5	57.2	0.86	4.77	Note (a)†
C- 9	110,200	111,000	187,270	21	55.5	1.35	7.52	Note (a)
C-10	111,000	111,000	192,000	20.5	54.0	1.38	7.68	Note (a)
C- 6	114,500	111,000	201,230	18.5	55.3	1.38	7.68	Note (a)
C- 8	119,000	120,000	241,500	18	56.8	2.18	12.1	Note (b)
C- 1	119,000	121,000	199,000	26	57.0	0.18	1	Note (a)
C- 2	122,000	124,000	198,000	26	55.8	0.14	7.78	Note (a)
C- 4	123,000	128,000	171,000	23	56.7	0.23	12.8	Note (b)
C- 3			228,000	22.5	56.7	1.5	83.3	Note (b)

*Unit: Per second $\times 10^{-3}$.

†Curves for C-5 and C-7 showed plateaus.

Note (a) Break did not occur at neck. Double neck; longitudinal split, brittle fracture.

Note (b) Single neck; longitudinal split, brittle fracture.

there is an increase of 11 and 12.1% in the tensile strength and yield point with a variation of strain rate of 0.00018 and 0.00138 per sec. respectively. For the same variation in strain rate, there is a decrease in the reduction of area and elongation of 16.5 and 47.2% respectively. The flow curves for specimens C-5 and C-7, the lowest strain rates used in the present series of tests, showed prominent plateaus. These are shown in Fig. 2. The flow curves for specimen C-1 (which was extended at the same rate as C-5 but in the "as-received" condition) did not exhibit the plateau phenomenon.

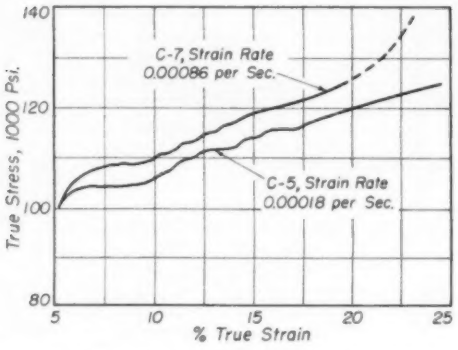


Fig. 2 — Flow Curves for Specimens C-5 and C-7

Figure 3 shows a magnified view of the specimens as ruptured. Rupture occurred with a "double neck" in all specimens where the strain rate did not exceed 0.00218 per sec. Specimens were not available to attempt a determination of exact strain rate where "double necking" gives way to the common single necking observed with most metals.

Hollomon and Jaffee, in their book, "Ferrous Metallurgical Design", state that the effect of strain rate on yield strength can be expressed by the following relation:

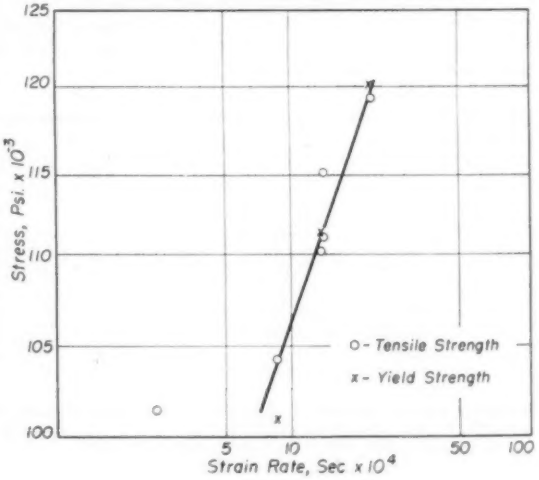
$$\sigma = K(\dot{\varepsilon})^n$$

where σ is the stress, $\dot{\varepsilon}$ the rate of strain, K a constant and n another constant that depends upon the strength of the material at a fixed strain rate. To test whether or not their relationship would hold for the case of molybdenum, the log of the stress is plotted against the log of the strain rate (Fig. 4) for data given in the table. As may be noted, there is a straight-line relationship for yield stress and, except for the initial few

Fig. 3 — View of "Double Neck" and Longitudinal Split. This kind of rupture developed only when strain rate did not exceed 0.00218 per sec. 2.5 ×

points, this same straight-line relationship exists for the tensile strength. The data obtained from the flow curves at constant strain but at various strain rates did not, however, yield straight-line curves. This may be due to inaccurate flow curves at the higher strain rates because of insufficient points.

Fig. 4 — Log of Stress Plotted Against Log of Strain Shows Straight-Line Relationship for Yield Stress and Tensile Strength. Data used are those given in table



Properties of Metals Used at Low Temperatures

By Our Special Representative

THE ANNUAL METALLURGICAL CONFERENCE and open house held at the National Bureau of Standards on May 14 and 15, 1951, was comprised of a three-session symposium on the "Influence of Low Temperatures on the Mechanical Properties of Metals" with a predominance of papers from outside the Government services. Nine papers and one narrated movie, including both theoretical and applied considerations, were presented. This symposium, attended by more than 250 metallurgists and engineers representing many parts of the nation, was one of a series on scientific subjects being sponsored by the Bureau in connection with its semicentennial celebration (1901-1951). Through the cooperation of the Office of Naval Research it was possible to include a foreign speaker on this program.

The opening paper, by R. L. Smith, G. A. Moore and R. M. Brick, of the University of Pennsylvania, a summary of a study of the influence of low temperature on the tensile properties of high-purity iron-carbon alloys containing 0.05 to 0.5% carbon, treated to obtain A.S.T.M. No. 5 grain size with medium pearlite, showed that yield point values increase along S-shaped curves with decreases in temperature to −192° C. (−314° F.). Graphs were presented showing that fracture stress for the alloys increased nearly linearly with decreasing temperature to about −150° C. (−238° F.) and then fell off rapidly as the temperatures were decreased further, indicating that the transition for all of these alloys occurred at about −150° C. Total strain decreased slowly with decreasing temperature until the transition was reached and thereafter occurred more rapidly. Flow stress values at constant strains increased at increasing rates with decreasing temperatures. Increases in carbon content caused nearly linear increases in yield point, slight increases in fracture stress, decreases in total strain and increases in flow stress at a constant strain and temperature.

Morgan Williams, of the Bureau of Standards, who discussed "Brittle Fractures in Ship Plates", indicated that weld failures in merchant ships, usually occurring at low temperatures and generally traceable to notch effects resulting from faulty design or welding, had cost this country about $50,000,000 during the last decade. Although the report showed that failures had been reduced considerably by improvement of design details and welding workmanship, it was stressed that these factors alone cannot entirely eliminate the failures, since many are traceable to the quality of steel, especially with respect to their notch sensitivity. Statistical interpretation of Charpy V-notch test data indicated that under the conditions existing in the structure of a ship, the probability of initiation of fracture in a plate increases markedly with increasing notch sensitivity of the steel, as measured by the 15 ft-lb. transition temperature. Correlation of these Charpy data with chemical compositions of the steels investigated showed that notch sensitivity increased with increased carbon, phosphorus, molybdenum and arsenic contents, and decreased with finer grain size and increasing amounts of silicon, manganese, copper and nickel. However, the combined effects of these elements are not simply additive.

A reasonably dependable basis for evaluating the maximum transition temperature based on the chemical composition and grain size of the steels studied was obtained by the formula:

(Max.) 15 ft-lb. transition temperature, °F. = $100 + 300 \times \%\ C + 1000 \times \%\ P - 100 \times \%\ Mn - 300 \times \%\ Si - 5 \times$ A.S.T.M. ferritic grain size number.

Although the thicker plates had higher transition temperatures, it was attributed to the fact that they had correspondingly coarser grains than the thinner plates.

STEELS FOR LOW-TEMPERATURE SERVICE

J. B. Austin, of the Research Laboratories, U. S. Steel Co., discussing "The Manufacture of Steels for Low-Temperature Service", pointed out that, while the notch toughness as indicated by the notched-bar impact test is one of the most satisfactory and widely used of the criteria for ascertaining the suitability of metals for

low-temperature service, the type of specimen, design of notch, and rate of straining must be considered in establishing a statistical index of low-temperature performance based on such tests.

The microstructure of ferrous metals in a general manner influences the transition temperature at which the material undergoes a change from tough to brittle behavior; the lowest transition temperature is obtained when the structure is austenitic. In ferritic steels, the heat treatment capable of producing the lowest transition temperature for a given hardness appears to be full martensitic hardening and subsequent tempering to the desired hardness level. A completely pearlitic structure obtained by continuous cooling at a rate to attain the desired hardness tends to give the highest transition temperature although it is lowered as the mean distance between the lamellae decreases. Intermediate transition temperatures are obtained with mixed structures of pearlite and tempered martensite. An addition of about 9% nickel yields a steel with a very low transition temperature, even as normalized and tempered. Dr. Austin's comments regarding the influence of grain size, carbon, phosphorus and manganese contents were substantially in accord with those stated by Dr. Williams.

It was pointed out that in controlling grain size, finishing temperature is very significant, the tendency being for decreasing transition temperatures in the steels finished at the lowest temperatures. For a silicon-killed steel containing 0.23% carbon and 0.45% manganese, transition was lowered about −6.7° C. (20° F.) for each unit decrease in A.S.T.M. grain size number. [It is about −1.1° C. (30° F.) in semi-killed steel.] In general, the transition temperature is lower the better the deoxidation of the steel, although other factors, such as heat treatment, may alter the results. Data indicated that heats deoxidized with aluminum and silicon produced the lowest transition temperature, the maximum benefit being obtained with high manganese content.

Quoting the results of Rinebolt and Harris, who investigated the effects on the transition of different elements in a base steel containing 0.30% carbon, 1.00% manganese and 0.30% silicon and having the same coarse pearlitic structure and grain size (A.S.T.M. 7 to 8), it was stated that small increases in carbon, molybdenum and phosphorus significantly raised the transition temperature. Silicon and copper had somewhat less effect, while chromium and boron appeared to cause no change. Additions of nickel in amounts up to 3% caused measurable lowering of the transition temperature and manganese produced a more marked effect in the same direction, being particularly effective when the ratio of manganese to carbon is high. An increase also was caused by titanium and vanadium in amounts of less than 0.2%, but additions above this caused decreases. Addition of an alloying element may change not only the transition temperature but also the shape of the energy-temperature curve. Dr. Austin observed that he was in full agreement with Dr. Williams, in that the effects of the elements noted were not simply additive when present as combinations in steel, since certain significant interactions of elements may occur.

ELASTIC PROPERTIES OF METALS

N. P. Allen, of the National Physical Laboratory, Teddington, England, who attended the meeting as the foreign guest and representative, presented some theoretical considerations of low-temperature effects on metals, based on recent studies by the National Physical Laboratories and other investigators in England and continental Europe. He pointed out that while most of the experimental work has attempted to determine the behavior of the common engineering metals and alloys as the temperature is lowered, there is at present a revival of interest in the elastic properties of metals, since they provide the most direct approach to the study of the mechanism associated with the behavior of metals and alloys at low temperatures.

Results of other studies reveal that changes in the crystallographic mechanism of slip with lowering in the testing temperature causes a change in the *mode* of slip. With aluminum, the first stage of deformation is much the same at all temperatures and it consists of the formation of widely spaced zones of simple slip. Further deformation at low temperatures produces more zones of simple slip at closer spacings until a minimum is reached, after which additional slip lamellae may appear in each zone. At high temperatures, the minimum spacing is wider and further deformation produces new slip lamellae in each zone. The greater strain hardening at low temperatures is attributed to the more numerous slip zones occurring at the low temperatures.

Investigations correlating the proof stress ratios to the type of lattice and to the temperature were also reviewed. Studies with high-purity iron at the National Physical Laboratory indicated that the V-notch bar impact transition

(Continued on p. 108)

DUCTILE IRON

approaches properties of cast steel; is readily produced by GRAY IRON FOUNDRY PRACTICE

The Chris Erhart Foundry & Machine Co., Cincinnati 3, Ohio, produced this Jordan plug, requiring strength and toughness, in ductile iron for Black-Clawson Co., a leading manufacturer of pulp and paper mill equipment.

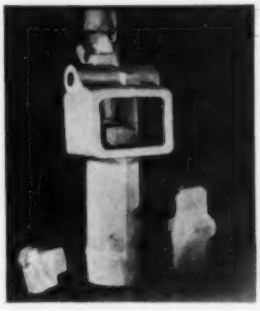
* * *

This high strength clamp can take a 90° twist without cracking or fracture ... because it is ductile iron ... cast for The Langslow Corporation, Rochester 9, N. Y., by The Acme Shear Company, Bridgeport 1, Conn.

DUCTILE IRON is a cast ferrous product that combines the *process advantages* of cast iron with many of the *product advantages* of cast steel.

In less than two years, ductile iron has attained wide acceptance, because it offers excellent castability, high mechanical properties, and good machinability. Parts cast in ductile iron show superior strength and pressure-tightness, high modulus and resistance to shock.

Typical current applications include bombsight parts, clutch drums, dies for automotive fenders and bumpers, electrical fittings, pistons for diesels, side frames for forging hammers, sprockets & gears, and many other parts.



Bison Castings, Inc., Buffalo, N. Y., cast this hydraulic jack cylinder in ductile iron for strength and pressure-tightness. Note, at right and left, sections cut from castings to show soundness.

AVAILABILITY

Send us details of your prospective uses, so that we may suggest a source of supply from some 100 authorized foundries now producing ductile iron under patent licenses. Request a list of available publications on ductile iron ... mail the coupon now.

The International Nickel Company, Inc.
Dept. M.P., 67 Wall Street, New York 5, N. Y.
Please send me a list of publications on: **DUCTILE IRON**

Name..... Title.....

Company.....

Address .....

City..... State.....

INCO SERVICE

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Properties of Molybdenum

Compiled by Robert M. Parke

Tensile Properties of Molybdenum

Form*	Condition	°F.	Strain Rate	Tensile	Yield	R. A.	Elongation
Single crystal[54]				50,000			
0.01-In. wire[55]	Annealed			90/110,000			
0.005-In. wire[17]	Drawn			200/260,000			
0.0012-In. wire[17]	Drawn			270/310,000			
½-In. rod[57]	Arc cast; hot rolled	80	60%/hr.	100,100†	99,800	60.9	32% in 1 in.
	Annealed 2200° F.	80	60%/hr.	73,600‡	50,100	55.6	55% in 1 in.
Rod[57]	Arc cast; hot rolled; recrystallized	80	1000 psi./min.	67,600	63,500	36	46% in 2 in.
	Same	1600	1000 psi./min.	34,400	11,600	84	46% in 2 in.
0.040-In. sheet[11]	Powder metallurgy; hot rolled; annealed 2000° F.	70		89,900			24%
½-In. rod[53]	Powder metallurgy; recrystallized	2000		33,250			27%
	Same	2400		15,000±			8%

*References on p. 83 to 94. †Hardness: Vickers 255. ‡Vickers 187. Other hardness data give Brinell 290 at −300° F.[58]; 220 Brinell at 70° F.[58]; Vickers 135 at 900° C.[30]; Vickers 90 at 1300° C.

Miscellaneous Physical Properties

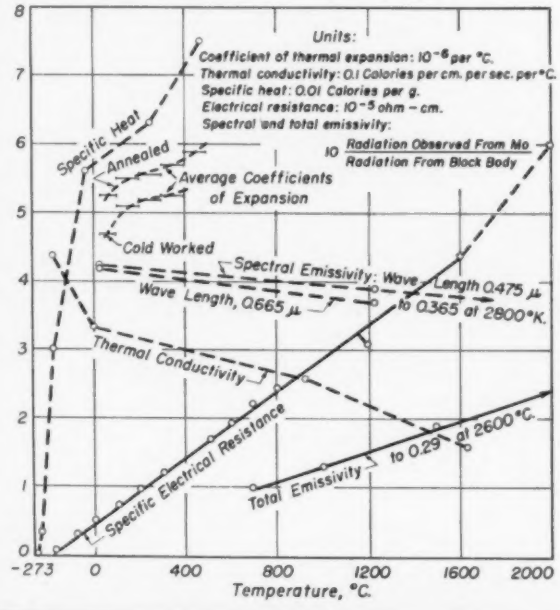
Modulus of rigidity (by torsional pendulum)[59]
17 × 10⁶ psi. at 75° F.
16.1 × 10⁶ psi. at 1100° F.

Poisson's ratio: 0.307 at 80° F.[57]
0.321 at 1600° F.[57]

Young's modulus
48.6 × 10⁶ psi. at −100° C.[60]
46 to 50 × 10⁶ psi. at 70° F.[6]
46 × 10⁶ psi. at 300° C.[60]
42.9 × 10⁶ psi. at 700° C.[60]

Creep strength at 1% per 100 hr. (tested in hydrogen)[61]
About 9700 psi. at 1650° F.
About 9000 psi. at 1750° F.
About 8400 psi. at 1850° F.

Optical, Thermal and Electrical Properties



Thermal Data

Melting point is 2622° C. ± 10° (4750° F.), the weighted average of 97 readings.[46, 47]

Heat of fusion is about 50 cal. per g.[48]

Boiling point[45] is 5960° K. (5690° C., 10,270° F.).

Heat of vaporization is about 1340 cal. per g.[54]

Thermal expansion,[43] $L/L_{300} = 5 \times 10^{-6} (T - 300) + 10.5 \times 10^{-10} (T - 300)^2$

Vapor Pressure[45]

Temp., °K.	Barye*	Evaporation†
1000	1.01×10^{-19}	
1500	3.44×10^{-9}	
2000	5.58×10^{-4}	5.34×10^{-9}
2500	6.58×10^{-1}	
3000	64	5.0×10^{-4}
4000	1.1×10^{4}	7.7×10^{-2}
5000	2.0×10^{5}	
6000	1.0×10^{6}	

*1 barye = 1 dyne per sq.cm. = 7.5006×10^{-4} mm. Hg

†Evaporation rate in vacuum. Unit = g. per sq.cm. per sec.

Front Line Protection...

MADE OF SHARON SPECIAL DEEP DRAWING HELMET STEEL

The designer of this head piece may never be listed alongside Dior or Dache, and the wearer quite probably will receive no Fashion Academy Award for originality, but there is no denying its popularity.

The steel used in the manufacture of this standard military helmet necessarily must be tough — yet pliable enough to take an extra-ordinarily deep draw without strain. It is made of a single piece of strip steel which has cold work hardening properties to stand maximum impact.

Expanding military requirements call for an ever increasing number of these helmets. As in World War II, a large percentage of them will be made from Sharon special deep drawing helmet steel.

* Specialists in STAINLESS, ALLOY, COLD ROLLED and COATED Strip Steels.

SHARON STEEL CORPORATION
Sharon, Pennsylvania

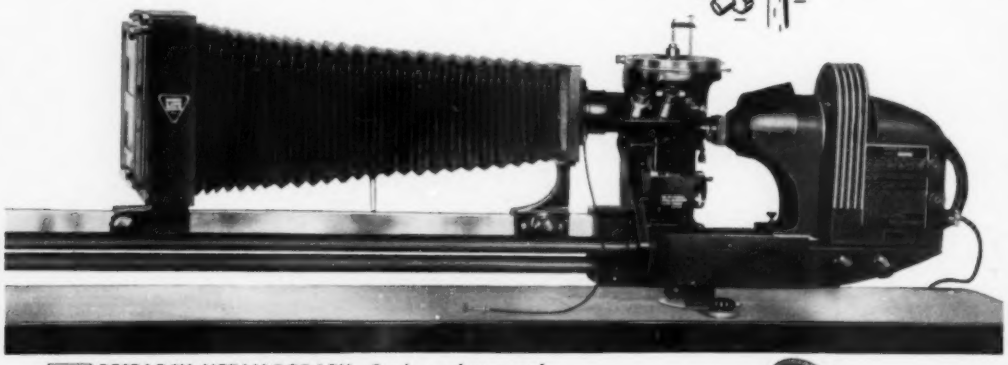
DISTRICT SALES OFFICES: CHICAGO, ILL., CINCINNATI, O., CLEVELAND, O., DAYTON, O., DETROIT, MICH., INDIANAPOLIS, IND., MILWAUKEE, WIS., NEW YORK, N. Y., PHILADELPHIA, PENNA., ROCHESTER, N. Y., LOS ANGELES, CALIF., SAN FRANCISCO, CALIF., MONTREAL, QUE., TORONTO, ONT.

SHARONSTEEL

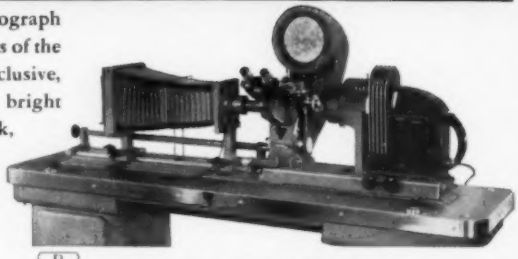
REDUCE WASTE . . .

FROM LADLE TO FINISHED PRODUCT

. . . in research and production . . . save materials and manpower . . . with the Bausch & Lomb complete line of metallurgical equipment

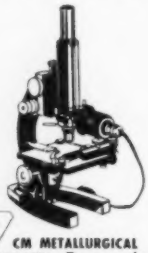


RESEARCH METALLOGRAPH—See it . . . photograph it . . . *four* ways! Four different accurate images of the same sample, for more complete identification. Exclusive, patented B&L features permit critical work with bright field, dark field or polarized light . . . with quick, easy change-over. For phase contrast work B&L accessories are simply, speedily attached. The "maximum use" instrument for visual observation and photomicrography. Catalog E-240.

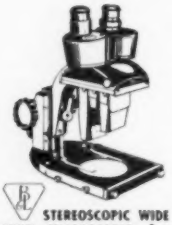


NEW! BALPHOT METALLOGRAPH—*All new* design! The economy of limited capacity instruments, with bright field, dark field or polarized light and phase contrast . . . and many other performance advantages of the highest-priced metallographs. Quick-action stage elevating device eliminates coarse adjustment. New *Magna-Viewer* projects bright, magnified screen images . . . ideal for grain size determinations and group viewing. Catalog E-232.

PHOTOMICROGRAPHIC EQUIPMENT MODEL L—With proper accessories *this one unit* provides visual microscopy, high and low power photomicrography, as well as photocopying. Catalog E-210.



CM METALLURGICAL MICROSCOPE—For examination of opaque objects, polished metal specimens, similar materials. Catalog E-223. Tri-Vert Illuminator (optional) provides bright field, dark field, or polarized light. Catalog D-108.



STEREOSCOPIC WIDE FIELD MICROSCOPES—Invaluable in preparation of polished metal specimens, study of fractures, porosity, macro-etched specimens and other low power metallurgical studies. Catalog D-15.

WRITE for complete information to Bausch & Lomb Optical Co., 638-7 St. Paul St., Rochester 2, N. Y.

Bausch & Lomb *Metallurgical* Equipment

Molybdenum A New High-Temperature Metal

By Robert M. Parke
Battelle Memorial Institute
Columbus, Ohio

SINCE the beginning of the first world war, the technical status of molybdenum has changed from that of a rare element to a metal essential to our national economy and demanded in quantities of nearly a million pounds a week.

The major use (and the one most responsible for its present place in the metallurgical world) is in steel, where it serves as a minor constituent to increase hardening capacity. This influence on steel is not unique with molybdenum but is shared with several other metals. Its acceptance by steelmakers rests on a firm structure of technical and economic facts, obtained largely during the last 25 years.

There are smaller but important uses for molybdenum which are described elsewhere. The purpose here is to discuss a *new* role for molybdenum — that is, its use as a structural material resistant to the damaging effects of temperature, and to give the various properties related to the new uses.

As a heat resistant material, molybdenum would be employed as a pure metal or as the major constituent of an alloy. It may turn out that it will be outstanding in this application, since the combination of high-temperature properties, abundance, and availability is unique. Furthermore, the need for such a material arises from the recent extraordinary developments in the generation of various forms of power by such heat engines as the gas turbine.

For many years the heat engine has been the greatest impetus for research in refractory materials. A basic need for them will exist, therefore, so long as the heat engine is the principal means for converting the energy of fuels into the several other forms of energy required for our national defense or desired by our highly mechanized industrial society. Consequently, progress in the improvement of heat resistant metals has been, and the future high-temperature use of molybdenum will be, closely related to the evolution of the heat engine — that is to say, the gas turbine — in the days to come.

The early steam engine of Newcomen and Watt, operating at just over 200° F., was not retarded in its slow development through any lack of constructional materials, and the trend in design did not even suggest a future need for heat resistant materials. Temperatures and pressures began to rise with the knowledge of the benefits of high temperature on engine performance derived by Carnot in 1824, and the Joule's doctrine of the conservation of heat (1843).

Until about 1940, the advancing requirements were seemingly being met by parallel developments in metallurgy, although operating temperatures reached and, in some instances, slightly exceeded 1000° F. However, in the late 1930's and especially during World War II, marked advances were made in other kinds of heat engines. Significant increases were occurring in the operating temperatures of gas turbines, rockets, various types of jet engines, rapid-fire engines, recoilless guns, and high-velocity guns.

Concurrent advances occurred in fuels to such an extent that it appeared that metallurgists were not keeping pace with the demands for metals possessing high strength and corrosion resistance at elevated temperatures. Furthermore, the temperatures to which the stressed metal parts were exposed reached such high values that one absolute upper limit, which is surely the melting point, seemed dangerously close.

The melting points* of currently acceptable heat resistant alloys lie between 2300 and 2800° F. (These are alloys which can be melted, cast, or hot formed to desired shape, with equipment now available and with modifications of familiar manufacturing processes.) Gas turbine blades and other parts in contact with the working fluid are operating at temperatures between 1300 and 1600° F. Higher temperatures are encountered in other heat engines. With flame temperatures for modern fuels of the order 5000° F., it becomes clear that — for long-range development of heat engines — consideration must be given to the improvement and

*That is, the temperature at which a liquid phase first appears throughout the alloy and thereby drastically lowers the strength.

Sources of Molybdenum

fabrication of constructional materials for use at much higher temperatures than now used.

To meet this situation, there seemed to be but two possible responses: Put forth a greater effort to discover more refractory materials or, through special design, maintain a greater difference in temperature between the working fluid and the hot parts of the engine.

Through clever design of cooling systems, the need for heat resistant materials can sometimes be circumvented. In other instances, cooling devices would be unreliable or prohibitively cumbersome or would lower the thermal efficiency too much. It is necessary, therefore, to examine both possibilities intently. This is the basis for the present expenditure of the very considerable sums of money for research on heat resistant materials.

The properties required are so varied that research must be on a very broad front, covering all refractory substances. Our understanding of the thermal and mechanical behavior of solids consists more of specialized experimental data than basic knowledge of the solid state. Consequently, it is strategic to divide the whole effort into separate research programs on specific materials with high melting points. Thus, individual programs of research are in progress on most of the high-melting metals and ceramics, and on high-melting materials such as carbon and mixtures of metals with ceramics.

The metal molybdenum offers great possibilities.* Its melting point is high: 4760° F. There are other metals with nearly as high a melting point and three (tungsten, 6170° F.; osmium, 4900° F.; rhenium, 5740° F.) with higher, but none of them are available in quantities adequate for the expected demands.

The significance of this new contribution that molybdenum could make to the national economy, if it turns out to be one solution to the problem, is clearly pointed out in the following words of N. P. Allen:[1]

"A large improvement in the average efficiency of power production would be as important as the discovery of several major coal or oil fields, and could be an important factor in improving the standard of civilized living. Technically, it requires that the temperature of the engines employed be raised from a range in which most metals and alloys behave as rigid elastic bodies to a range in which they flow continuously under load. During the coming decades a new kind of engineering must be developed to meet these conditions, and a new range of materials must be found for all the many components which in the new engines will operate at a red heat for months and years on end."

SOURCES AND AVAILABILITY

The principal minerals containing molybdenum are molybdenite (MoS_2) and wulfenite ($PbMoO_4$), the former providing by far the larger proportion of the metal.[2] No natural occurrences of metallic molybdenum are known.[3]

F. W. Clarke and H. S. Washington[4] state that the average proportion of molybdenum in the igneous rocks of the earth's crust is about 10^{-6}%. Other estimates[5] range between 10^{-7} and 10^{-5}%. Thus, molybdenum is one of the scarcer elements in the earth's crust.

Marginal and submarginal ore deposits occur throughout the world,[5, 6] but the United States has led the world in its production and consumption. We are in a most favorable position, having produced, up to the present, nearly 90% of the world's supply.[7, 2] Chile, which is now the largest foreign producer, and 15 other countries account for the remainder. A new molybdenum mine is expected to begin operation during this year in Serbia.

The six states, Colorado, Utah, New Mexico, Arizona, California, and Nevada (listed in order of output), produce practically all of the U. S. metal. A large portion (about 50% in 1948 and 1949) of this molybdenum is recovered as byproduct from copper concentration, and this source is obviously limited by the output of cop-

*Most of the information for this report has been gathered as part of a research program on molybdenum, sponsored by the Office of Naval Research.

Bibliography

1. "Metallic Creep and Creep Resistant Alloys", by A. H. Sully, Interscience Publishers, Inc., New York. (Foreword by N. P. Allen.)

2. "Molybdenum", by Hubert W. Davis, Bureau of Mines, Minerals Yearbook, Preprint, 1949, 7 p.

3. "Handbook of Chemistry and Physics", 30th Ed., Chemical Rubber Publishing Co., Cleveland.

4. "The Average Chemical Composition of Igneous Rocks", by F. W. Clarke and H. S. Washington, *Proceedings* of the National Academy of Sciences, V. 8, 1922, p. 108 to 115.

5. "A Comprehensive Treatise on Inorganic and Theoretical Chemistry", by J. W. Mellor, Longmans, Green and Co., New York, V. 11, 1931, p. 486.

6. "Molybdenum as a Heat-Resistant Metal", by Robert M. Parke, Battelle Memorial Institute Technical Report to Office of Naval Research, Contract No. N9onr 82100, April 10, 1950.

7. "Molybdenum", by Alan

Poor Resistance to Oxidation

per. The most important single source is the world-famous deposit of molybdenite at Climax, Colo., operated by the Climax Molybdenum Co. The Climax deposit had, up to 1946, yielded 85% of the world's molybdenum.[8]

The peak production was in 1943, when the U. S. output reached 66,000,000 lb. of molybdenum. In 1949, it was about 23,000,000 lb.

The fluctuations in the demand make it difficult to estimate the rate of exhaustion of the ore deposits. Pehrson[9] estimated, as of 1944, that the known commercial reserves would last 422 years if mined at the 1935-1939 annual rate. On the same basis, he estimated that there exists from 100 to 500 years' additional supply from submarginal and highly speculative resources. Gaddis,[10] in comparing these estimates with those for other metals, commented that "molybdenum is one of the few bright spots in our generally bleak mineral resources picture".

PROBLEMS TO BE MET

The high melting temperature of molybdenum, relative to present successful heat resistant alloys, and its abundance and availability are not its only attractive properties. It will be seen that molybdenum has desirable mechanical and other thermal properties. However, the metal cannot at once be put to general use in the high-temperature field. A more complete set of measurements of its physical properties must be made. Improvements in its fabrication must be worked out. Finally, means must be found to overcome some unfavorable properties before the full potentialities can be realized. These matters will now be discussed.

Surface Stability — In addition to having a melting point above the temperature of the intended use, a successful high-temperature metal must possess a stable surface, adequately inactive to its environment — that is, it must not react at too high a rate with the ambient atmosphere, and it must not evaporate too fast. From the vapor pressure it can be shown that molybdenum evaporates at a low rate below about 3000° F. Nevertheless, since its vapor pressure is too high for it to serve as an incandescent lamp filament, it is evident that this property should not be ignored when long service and high dimensional stability are required.

As a matter of fact, molybdenum does have poor surface stability in air at high temperatures, due to a high rate of oxidation. This is its most troublesome property. The oxide, MoO_3, forms and vaporizes at an appreciable rate above 1400° F., even when the atmosphere contains but a few per cent of oxygen. Unfortunately, the rate of oxidation is very much higher than for metals whose oxides are practically nonvolatile up to 3500° F., remaining on the surface to retard further reaction. For example, at 1800° F. in air flowing slowly, the surface of molybdenum recedes at the rate of 0.02 to 0.05 in. per hr. This rate of loss of metal is intolerable for most uses. Improvement of surface stability represents the most important and, at the same time, the most difficult problem that must be solved before the metal is widely used in heat engines. Several ideas are being developed; each gives hope of meeting the requirements of some of the high-temperature applications; none is free from serious objections.

One method of protection is known as cladding, in which another more oxidation resistant metal is welded to the surface of molybdenum by rolling. This process has been investigated and improved by Bruckart, Whalen, Jaffee, and Gonser.[11] From their work it can be said that cladding is feasible with nickel or with an alloy of 90% platinum, 10% rhodium. In creep tests on molybdenum clad with 15% its thickness with "A" nickel on each side, the minimum creep rate at 1800° F. and 5000-psi. stress was 0.0001% per hr. The obvious limitations of Inconel and nickel clad is the relatively low melting points of the surface metal, and of the platinum alloy is its high cost and scarcity. Even so, cladding will meet some high-temperature requirements.

Kissock, *Mineral Industry*, McGraw-Hill Book Co., New York, V. 48, 1939, p. 421 to 424.

8. "Climax Molybdenum Issue", *Mining and Metallurgy*, V. 27, June 1946, p. 297 to 384.

9. "The Mineral Position of the United States and the Outlook for the Future", by Elmer W. Pehrson, *Mining and Metallurgy*, V. 26, 1945, p. 204 to 214.

10. "Molybdenum as a Strategic Material", by Walter D. Gaddis, a report submitted to the Department of Metallurgical Engineering, Carnegie Institute of Technology, undated (about 1946).

11. "Molybdenum Alloys and Protection by Cladding", by W. L. Bruckart, S. J. Whalen, R. I. Jaffee and B. W. Gonser, The RAND Corp., April 25, 1950.

12. "The Formation of Molybdenum Disilicide Coatings on Molybdenum", by E. A. Beidler, C. F. Powell, I. E. Campbell and L. F. Yntema, *Journal* of the Electrochemical Society, V. 98, January 1951, p. 21 to 25.

13. "Fansteel Tungsten and Molybdenum", Fansteel Metallurgical Corp., North Chicago, 1950.

14. Sixth Quarterly Report on Contract No. N9onr 82100, Battelle Memorial Institute to Office of Naval Research, Nov. 1, 1950.

Use of Stable Coatings

A second method of surface protection is by the vapor-phase deposition of silicon. This method has been developed to a very promising stage by Beidler, Powell, Campbell, and Yntema.[12] They report that a silicon coating 0.025 mm. thick completely protects the underlying molybdenum for 4000 hr. in air at 1000° C. (1830° F.) and for 30 hr. at 1700° C. (3100° F.). The principal limitations of this protection method are *(a)* the coating may fail when plastic strain occurs, and *(b)* the coating must be perfect in its coverage, a small flaw permitting loss of molybdenum over a relatively large area.

This method of protection, while still being improved, has had notable success. The Fansteel Metallurgical Corp.[13] has recently announced the availability of molybdenum bar, rod, wire, and tubing with siliconized coatings.

The third method of protection involves a ceramic coating.[6] This method, too, probably will be suitable for certain applications but has not yet shown as much promise as the two methods just mentioned.

The fourth method of protecting molybdenum against oxidation is by electroplating. Some success[14] has been reported, but this method also has been inadequately investigated. The information needed here concerns rates of diffusion of the plated metal in molybdenum, and the composition limits that give protection, so that the required thickness of plate can be estimated for specified periods.

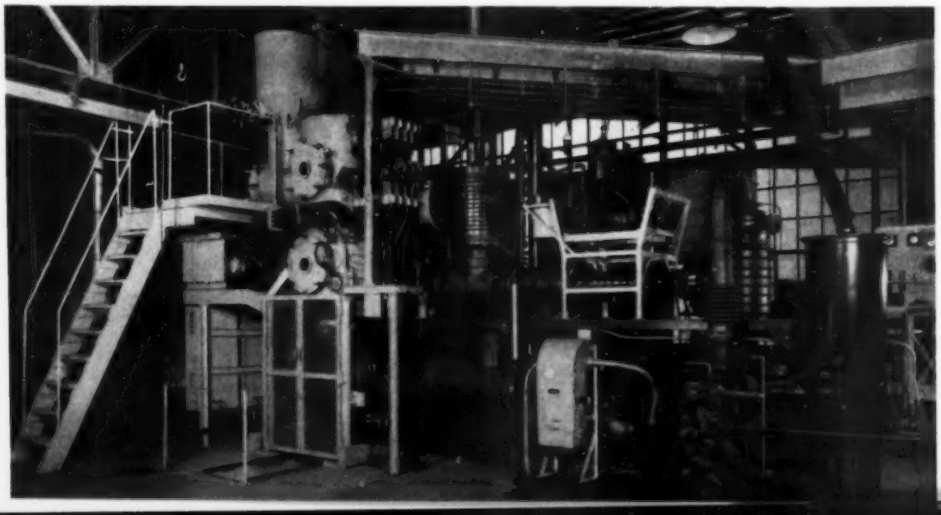
The last method involves the alloying of molybdenum with an element or elements which suppress the formation of the volatile MoO_3. This method has only recently been investigated and has achieved, so far, the least success. However, it has been only superficially surveyed. An important advantage which an oxidation resistant alloy would have over coated molybdenum is the capacity for self-healing in the event of damage to the surface. Those oxidation resistant alloys which have so far been developed are brittle and consequently difficult to fabricate.[15, 14]

Fabrication — Molybdenum powder is the starting material for fabrication into rod, wire, sheet, plates, and tubes. The powder is obtained by reducing molybdenum trioxide or ammonium molybdate in an atmosphere of hydrogen.

Although molybdenum was first obtained in elemental form by P. J. Hjelm in 1782,[5] its high melting point and reactivity with oxygen of the air prevented its production in solid, coherent and ductile form for over a hundred years. The many early attempts to make solid ductile bodies of molybdenum by melting[5] failed because of contamination from the atmosphere or the crucible. Success was attained as a byproduct of the experiments by Coolidge and Fink which resulted in ductile tungsten.[16] In 1910, Fink[17] reported the properties of ductile molybdenum in the form of wires made by the methods of powder metallurgy. The use of molybdenum as a metal begins, therefore, with this important pioneering work of Colin Fink.

In the form of wire and light-gage sheet, it has been used in lamps and electron tubes as filament supports and hooks, lead-in wires, and grids. For such uses, large pieces of molybde-

Fig. 1 — Equipment Recently Installed by Climax Molybdenum Co. for Melting and Casting Ingots up to 1000 Lb. in Weight. Vacuum equipment (powered by 25-hp. motor) is under and at right of power leads; feeding and compacting equipment for consumable molybdenum electrode at top left; melting unit underneath



Manufacture of Large Ingots

num are not needed. Resistance to oxidation also is not a requirement, since the bulbs or tubes are highly evacuated or contain only an inert gas like argon.

Up to 1940, a powdered metal compact of eight pounds was the largest ordinarily produced. It was evident that the limitation in size, inherent in the pressing equipment then available, would hamper molybdenum as a material of construction. During World War II, significant progress was made in fabrication of larger pieces of molybdenum, and two successful solutions to the problem have been found.

Westinghouse Electric Corp.[18] has modified the powder metallurgy method so that sintered and worked bodies weighing up to 500 lb. are now available. Climax Molybdenum Co. developed a method of melting and casting 1000-lb. ingots.

Since molybdenum is the highest melting metal being fabricated by a melting process, it is of interest to describe briefly the Climax process[27] whose equipment is pictured on p. 84. Melting takes place in an alternating-current arc which operates between a vertical, consumable, molybdenum electrode and a pool of liquid metal. Contamination of the melt is avoided by enclosing the process in an evacuated space (or by use of an inert gas).

Fig. 2 — 994-Lb. Ingot Produced in Equipment Shown on Opposite Page

The consumable metal electrode is formed continuously by extruding molybdenum powder through a special die. This electrode must be strengthened slightly by sintering, which is done continuously and simultaneously by resistance to the electrical current it carries into the arc. The lower, arc-holding end of the electrode becomes hot and drips molybdenum into the pool below. This pool is held in a water-cooled hollow cylinder which serves both as melting chamber and casting mold as it becomes filled. Some purification takes place during the melting as a result of the low pressure; that is to say, the vacuum can do more than merely protect the molten metal from contamination.

An essential part of the process is the lowering of the oxygen content below 0.003%. This can be done by adding a small amount of carbon and pumping it off as carbon monoxide. If the oxygen content of the melt is much above 0.003%, an oxide of molybdenum will precipitate at grain boundaries upon solidification. This precipitate, when it covers a small portion of the intergranular areas, makes cast molybdenum practically unforgeable.

For the present, at least, size is no longer a major limitation to the use of molybdenum as a constructional metal. Improved rolling and forging schedules for the large cast ingots and pressed billets must be worked out, but success will undoubtedly come with experience and with knowledge of the relations of such variables as temperature, strain rate, level of impurities, stress system, and strain at fracture.

The forming or shaping of molybdenum by rolling, machining, stamping, and spinning has advanced rapidly lately and presents no unusual difficulties. The status of the American industry was recently reviewed by Swartz in *Metal Progress* for August 1950. Gelock[18] stated that sheet can be spun in thicknesses up to 0.032 in.

Electroforming and electroplating of molybdenum have been studied by several investigators[20, 21] but these methods are not yet commercial, except, perhaps, where a very thin film is to be laid over another metal.

Methods of joining by brazing or by welding have also been worked out.[22] However, a molybdenum-to-molybdenum weldment which is ductile in a slow-bend test at room temperature has resisted many attempts. Heuschkel[23] has shown that ductility increases above 200° F. in some weldments, indicating that one effect of welding is to increase the temperature of transition from ductile to brittle behavior. The need for room-temperature ductility in molybdenum weldments is so great that this problem is now being studied in several laboratories.

Welding Techniques Under Study

Joining of molybdenum by spot welding has been practiced in the lamp and vacuum tube industry for many years, but since a high-strength, high-ductility weldment is not essential, very little thought was given to perfecting the techniques. This is but another example of how the metal's present use in vacuum tubes is unable to provide the experience and background essential to the new intended use in high-temperature engines.

Much more detailed knowledge of the effects of impurities on the physical properties of commercial molybdenum is desirable. About 0.05% total are present; the most conspicuous impurity elements are[6] carbon, oxygen, nitrogen, hydrogen, silicon, chromium, tin, bismuth, iron, manganese, and copper. It will be difficult to attain uniformity through processing control without determining their influence on at least a few of the important properties, such as ductility and creep strength.

NEED FOR MEASUREMENT OF MECHANICAL PROPERTIES

The mechanical properties demanded for various uses in lamps and vacuum tubes were easily met, once the special difficulties in fabricating molybdenum by powder metallurgy were subdued by Fink. Stresses and stress concentrations were low, and ductility requirements moderate. Mere existence in the form of wire or sheet was usually sufficient evidence that mechanical properties would be adequate.

For high-temperature engineering use, the stresses, strain rates, and complexity of stress will be limited only by the best resistance to flow and fracture that can be given the metal.

Much more complete and detailed knowledge of the mechanical behavior of molybdenum is therefore needed. Data on the mechanical properties are needed over a wide range of temperature and when exposed to combustion products and other hot gases. Such research must be from the point of view of new uses.

Fig. 3 — Molybdenum's Workability Shown by Cylinders for High-Frequency Electrical Sets, Spot Welded From 0.010-In. Sheet. (Westinghouse Electric Corp.)

Fundamental knowledge of the factors that control ductility is especially needed. This will be useful in fabricating, as well as in using, molybdenum.

In recognition of this need, fairly extensive programs of research have been initiated at Battelle Memorial Institute and other laboratories. Some of the most recent data are given in the section on physical properties and in the data sheet, p. 80-B.

ALLOYS OF MOLYBDENUM

Pure metals usually find very limited use as materials of construction because they are characteristically lower in strength than their alloys at all temperatures except near the melting point of the basis metal. The investigation of molybdenum alloys, therefore, represents one of the most important phases of present study. It may also uncover a solution to the very difficult high-temperature oxidation problem.

15. "Arc-Melted Molybdenum-Rich Chromium-Molybdenum Alloys", by H. D. Kessler and M. Hansen, *Steel*, V. 125, Oct. 10, 1949, p. 147.

16. "Ductile Tungsten", by Samuel L. Hoyt, *Metals and Alloys*, V. 6, 1935, p. 11 to 18.

17. "Ductile Tungsten and Molybdenum", by C. G. Fink, *Transactions* of the American Electrochemical Society, V. 17, 1910, p. 229 to 234.

18. "Molybdenum: Practical Structural Material", by John Gelok, *Westinghouse Engineer*, V. 7, September 1947, p. 156 to 159.

19. "Arc-Cast Molybdenum Probed for High-Temperature Utility", by J. L. Ham, *Steel*, V. 128, Jan. 15, 1951, p. 106 to 108.

20. "The Electrodeposition of Chromium, Molybdenum, and Tungsten", by L. F. Yntema, *Journal* of the American Chemical Society, V. 54, 1932, p. 3775 to 3776.

21. "The Electrodeposition of Molybdenum from Aqueous Solutions", by Sister Mary Joecile Ksycki and L. F. Yntema, *Transactions* of the Electrochemical Society, V. 96, July 1949, p. 48 to 56.

22. "Present Status of the Art of Molybdenum Fabrication", by Carl E. Swartz, *Metal Progress*, V. 58, August 1950, p. 181 to 184.

Mo-Cr Alloys Oxidize Readily

While molybdenum-base alloys are being made and studied in several laboratories, progress has not reached a point where specific compositions can be selected for particular applications.

Silicon — Bruckart, Whalen, Jaffee, and Gonser[11] examined a large number of binary alloys of molybdenum. One of the most interesting, from the standpoint of good mechanical properties combined with ease of fabrication, contains 0.25% silicon. This has a room-temperature tensile strength of 109,000 psi. and a uniform elongation of 12% (unalloyed molybdenum has 90,000 psi. tensile and 9% elongation).

A valuable part of this investigation was the determination of the alloy limits which could be hot rolled at 1250° C. (2275° F.) and also retain at least 1% elongation in the tension test at room temperature and with a strain rate of 0.016% per min. These limits for binary systems are Al, 0.8%; Cr, 2%; Co, 0.3%; Fe, 0.3%; Ni, 0.05%; Si, 0.3%.

Chromium — Kessler and Hansen[24] melted molybdenum-chromium alloys with chromium up to 36% in argon, using an electric arc. They measured weight losses of the alloys due to oxidation in still air at 1200, 1500, and 1800° F. At 1200° F., the rates of oxidation of all the alloys, as well as for pure molybdenum, were less than 1 mg. per hr. per sq.cm. The oxidation rates at 1500 and 1800° F. decreased with increase of chromium beyond 1.2% Cr, but were still high at 36.3% Cr. For example, at 1800° F., the weight loss in air is 60 mg. per hr. per sq.cm. for the 36.3% chromium alloy. Unfortunately, chromium with its stable, low-density oxide, which is so effective in reducing the rate of oxidation of iron, is unable to arrest the formation of the volatile oxide of molybdenum.

Kessler and Hansen noted that increasing chromium reduced the forgeability of the alloys. Lack of workability or brittleness is an important drawback to commercial applications, and information on embrittlement produced by specific elements is an important aspect, for it probably will be necessary to add rather large quantities of other metals to molybdenum in order to secure oxidation resistance.

Solid Solutions — Ham[25] has reported on an extensive investigation of molybdenum alloys

Fig. 4 — New Precision Mill in Westinghouse Research Laboratories, Hot Rolling Molybdenum Strip. Note oxide smoke arising from hot strip and deposit of oxide on cold rolls

23. "Welding High-Purity Molybdenum", by Julius Heuschkel, *Iron Age*, V. 162, Dec. 16, 1948, p. 87 to 89.

24. "A Study of Arc-Melted Molybdenum-Rich Chromium-Molybdenum Alloys", by H. D. Kessler and M. Hansen, *Transactions* of the American Society for Metals, V. 42, 1950, p. 1008 to 1032.

25. "An Introduction to Arc-Cast Molybdenum and Its Alloys", by J. L. Ham, American Society of Mechanical Engineers, Paper No. 50-A-70, 1950.

Solid Solution Alloys More Promising

which were prepared by melting in the arc, either in vacuum or in argon at one atmosphere pressure. Binary alloys of molybdenum and Be, Si, Ni, Co, Fe, Al, Zr, Cr, V, Ti, Cb, Ta, and W were prepared. The hardnesses of the alloys were determined at room temperature and at elevated temperature.

For certain temperatures in the range 2000 to 2700° F., the solubilities of Si, Ni, Co, Al, and Fe were determined by X-ray measurements of lattice parameters. These solubility limits served to guide the subsequent selection of alloys for more detailed study, it being assumed that the difficulties of hot working the alloys would increase markedly as the quantity of any second phase increased. Some such simplifying assumptions are necessary in laying the groundwork for the metallurgy of a new or little-known metal. In any event, an enormous quantity of experimental work is entailed in such an undertaking, so that an orderly approach, which includes a means of selecting the most probable compositions from the multitude of possibilities, is desirable.

Several of the alloys were impact-extruded at 2500 to 2600° F. and hardnesses after extrusion and in the fully recrystallized condition were measured. Ham made the interesting observation that the increase in hardness due to work hardening was proportional to the increase due to solid-solution hardening — that is to say, one linear relation between the two kinds of hardening held for the elements B, W, Ti, Al, Cb, V, Ta, and Zr. The relation was independent of element and amount if the limit of solid solubility was not exceeded.

Ham investigated the response to heat treatment of a number of the alloys through hardness measurements. He found that a binary alloy containing 0.10% beryllium was the most responsive; its hardness varied from about Vickers 225 when slowly cooled, to about 380 when cooled rapidly from 3200° F.

His essential objective was to develop arc-melted alloys with the highest strength at elevated temperatures that could also be hot formed by well-known methods.

Two other broad investigations of molybdenum alloys are in progress at Battelle Memorial Institute. One, under the sponsorship of the Office of Air Research, seeks to develop, by powder-metallurgy methods, molybdenum alloys of the highest strength at elevated temperature that can be hot rolled. The other, under the sponsorship of the Office of Naval Research, is searching for molybdenum alloys having resistance to oxidation at high temperature.

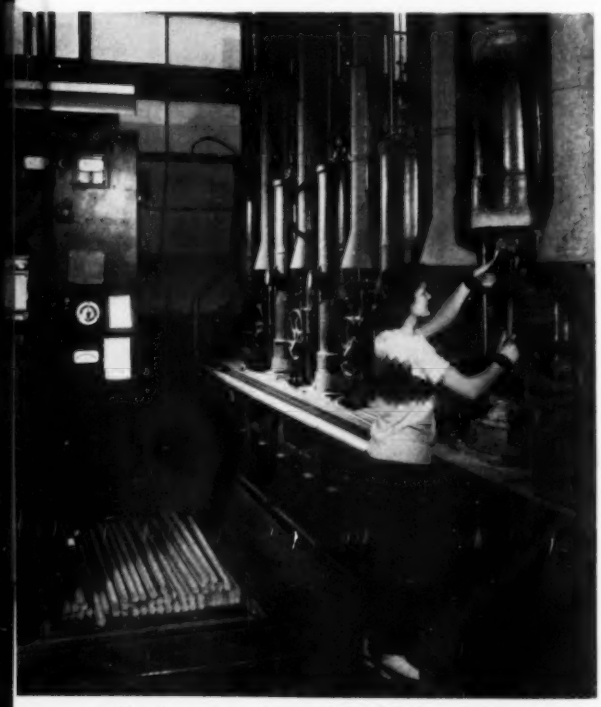


Fig. 5 — In the Process Used by Fansteel Metallurgical Corp. Pure Molybdic Anhydride Is Reduced by Hydrogen in Tube Furnaces, the Powder Compacted Into Bars in a 3000-Ton Hydraulic Press, and the Bars Sintered by Passing a High-Amperage Electric Current Through Them. This illustration shows five water cooled sintering furnaces, one being loaded

TERNARY ALLOYS

H. J. Goldschmidt has investigated the Fe-Cr-Mo equilibrium system (reported by Tom Bishop, *Metal Progress*, May 1951). A ternary compound was found which was approximately represented by the formula Fe_4CrMo_2. He suggested that useful heat-resistant molybdenum-rich alloys would occur in two regions of the ternary diagram. In one region, Mo varied between 60 and 92% and Fe from 0 to 5%. The other was elliptical in shape with the major axis extending from about 92% Mo, 2% Cr to 77% Mo, 14% Cr, and the minor axis extending from 84% Mo, 10% Fe to 87% Mo, 5% Fe.

Purity and Structure Control Ductility

Ductility is certainly a characteristic property of metals; perhaps it is the most valuable. It is a complex property, not easily defined. For present purposes it may be thought of as equivalent to the total plastic strain to fracture.

A certain minimum amount of ductility is demanded of any solid metal that does anything more than sit in a museum's showcase, or form the basis of a chemical reagent. This arises from requirements in its fabrication, as well as common use. A metal is expected to survive far greater thermal and mechanical shock and resist more severe stress-raisers than glasses or ceramics. In other words, it must be ductile, not brittle. Lacking this requirement for ductility is often the only reason a ceramic will not serve successfully. At the same time, adequate ductility must be attained in a new metal; until that is provided, its brittleness will be the chief retardant to its technological progress.

Ductility is not readily developed in molybdenum. In this respect, it is similar to tungsten. Furthermore, the moderate amount of ductility imparted to it by careful processing is lost in certain subsequent heat treatments or uses. Since this matter is of such great importance for usage at elevated temperatures, ductility and the factors affecting it will be discussed in detail.

Ductility of molybdenum, in common with that of most other metals, increases with increase in temperature, with decrease in strain rate,* with decrease in restraint imposed by biaxial or triaxial tension, and (usually) with increase in purity. Very probably there are complex interactions between these relations, augmenting the difficulties in comprehending the flow properties.

One important result of the research on molybdenum at Battelle Memorial Institute is that purity is a dominant variable in determining its ductility. It has been shown by Fischer and Jackson[26] and also by citations in Battelle Quarterly Reports that intergranular brittleness at room temperature will occur in arc-melted molybdenum if there is sufficient molybdenum carbide at the grain boundaries. As little as 0.02% carbon will suffice. Since it had previously been shown that an intergranular oxide[27] also caused intergranular brittleness, the relation between intergranular brittleness and purity seems well established.

In addition to the intergranular type of brittleness, molybdenum also exhibits transgranular brittleness with fracture on {100} planes — probably also due to impurities, although the exact cause is the subject of considerable study.

It is remarkable that only intergranular or transgranular fracture occurs in molybdenum near room temperature. The shear type of fracture has not been observed at Battelle so far, and its existence has not been reported in the literature. (There is a suggestion of a shear type of fracture in the high reduction of area measured in high-temperature tensile tests.)

Transgranular brittleness also occurs in cold rolled sheet when it has been cross rolled during manufacture. Under these circumstances, it is associated with preferred orientation and a fracture surface at 45° to the direction of rolling. The fracture is on {100}.[28]

Both transgranular and intergranular brittleness occur in molybdenum weldments. Since porosity is a usual accompaniment, impurities may be assumed to account for at least part of this brittleness. Microcracks are also sometimes seen, so the cooling rate must be important.

Several investigators[28, 29, 30, 31] found that ductility at room temperature was much reduced after the sample had recrystallized at high temperature. Usually the maximum ductility at 70° F. is obtained by a 15 to 30-min. anneal at 2100 to 2200° F. — a so-called "recovery" treatment, wherein very little recrystallization occurs, as a rule, and the "fibrous", worked structure is retained. The embrittling temperature is usually above 2500° F., but it varies widely and seems to depend on the source (past history) of the molybdenum. At the higher temperatures,

*For a discussion of molybdenum's sensitivity to strain rate and the phenomenon of "double necking", see the article by Messrs. Maddin and Pond on p. 76.

26. "The Ductility of Cast Molybdenum", by R. B. Fischer and J. H. Jackson, *Transactions* of the American Institute of Mining and Metallurgical Engineers, V. 188, September 1950, p. 1149.

27. "The Melting of Molybdenum in the Vacuum Arc", by Robert M. Parke and J. L. Ham, American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2052, 1946; *Metals Technology*, V. 13, September 1946, 12 p.

28. "Some Properties of Rolled Molybdenum Sheet", by C. E. Ransley and H. P. Rooksby, *Journal* of the Institute of Metals, LXII, 1938, p. 205 to 214.

29. "Effect of Heat Treatment on Tensile Strength and Elongation of Molybdenum Plate in Different Directions", by Hajime Kioka, *Proceedings* of the World Engineering Congress, Tokyo (1929), V. 36, 1931, p. 183 to 195.

30. "The Effect of Working on the Physical Properties of Molybdenum", by J. W. Marden and D. M. Wroughton, The Electrochemical Society Preprint, V. 89, 1946, p. 30; *Transactions* of the Electrochemical Society, V. 89, 1946, p. 216 to 228.

recrystallization converts the fibrous worked structure to equiaxed grains, and it is inferred that a fibrous structure is essential for maximum ductility. This view is supported by long experience in producing wire and sheet by swaging, drawing, rolling, or otherwise working molybdenum. This effect is observed for metal consolidated either by the methods of powder metallurgy or by arc melting; therefore, it cannot be wholly attributed to the closing of the voids in compacts. At any rate, this type of embrittlement needs further study, since it has been demonstrated, in a few instances,[6] that fully recrystallized equiaxed molybdenum obtained by heating above 2500° F. can retain most of its ductility.

The fibrous structure cannot, therefore, be the only significant factor. In the light of what is now known concerning the effect of impurities on ductility, another inference seems more reasonable. That is this: that for a given but at present unknown level of impurities, the fibrous structure may have the greater ductility, but for high-purity molybdenum, grain shape may not be an important factor.

Transition Temperature of molybdenum (that is, the temperature below which fracture occurs with practically no prior plastic deformation) is dependent upon purity, stress system, strain rate, and the previous thermal and mechanical history. Ham[25] made impact tensile tests on arc-cast molybdenum, rolled and then annealed at 2200° F., and found the transition from tough to brittle fracture at about 250° F. The method of testing — that is, the degree of restraint along the plane of fracture — is important, for in the V-notch Charpy impact test, the transition temperature for this same metal is about 750° F. (For molybdenum annealed at 3350° F. the transition temperature is about 1480° F. for Charpy impact specimens.)

In recent experiments at Battelle Memorial Institute, it has been found that the transition temperature, as measured by a bend test, can be lowered several hundred degrees Fahrenheit by decreasing the amount of impurities in the metal.

For high strain rates (for example, in the impact tensile test), and with uniaxial tension, the transition temperature of commercial molybdenum is above room temperature, which means that troubles may be expected from fragility of parts during manufacture and assembly. It would be very desirable to lower the transition temperature below room temperature for those conditions of stress and strain rate that the metal will encounter in normal engineering use.

In experiments to be reported in detail in a later publication, it has been shown that the ductility can be changed by heat treatment other than that causing recrystallization. It seems that many, if not all, of the subtle changes in ductility observed in iron can be expected in molybdenum. The exception, of course, will be those effects in iron due to transformation, i.e., changes in crystal structure. No solid-state phase change has been found in molybdenum.

The phenomenon of a sharp yield point has been observed in molybdenum[32, 33] and since a sharp yield point is attributed to the presence of an interstitial element, it may be assumed that some small atom — possibly nitrogen — is dissolved in amounts that the tensile test can detect.

The most important future research on the ductility of molybdenum will be the identification of those impurity elements that influence it, for good or for bad. Since intergranular brittleness and probably also transgranular brittleness are dependent upon composition, the distribution and form of impurities must also be studied.

PHYSICAL PROPERTIES

Until a few years ago, the physical properties of molybdenum that were studied and measured were those pertaining to its use in small parts in lamps and in vacuum tubes. A new set of properties, related more to engineering use than to electrical use, must now be obtained.

31. "Molybdenum and Molybdenum-Base Alloys Prepared by Powder Metallurgy Techniques", by W. L. Bruckart, S. J. Whalen, R. I. Jaffee and B. W. Gonser, Topical Report to The RAND Corp., April 15, 1950.

32. "Distortion and Yield Point of Molybdenum", by P. Tury and Stephen Krausz, *Nature*, V. 139, 1937, p. 30 to 31.

33. "Effect of Molecular Nitrogen on Molybdenum at High Temperatures", by P. Tury and Stephen Krausz, *Nature*, V. 138, 1936, p. 331.

34. "The Nature of the Chemical Bond", by L. Pauling, Cornell University Press, Ithaca, New York, 1939, 429 p.

35. "Crystal Structure and Chemical Composition", by V. M. Goldschmidt, *Berichte*, V. 60, 1927, p. 1271.

36. "The Sizes of Ions and the Structure of Ionic Crystals", by L. Pauling, *Journal* of the American Chemical Society, V. 49, p. 765.

37. "The Theory of the Properties of Metals and Alloys", by N. F. Mott and H. Jones, Clarendon Press, Oxford, England, p. 318.

38. "Series in the Arc Spectrum of Molybdenum", by C. C. Kiess, Scientific Papers of the Bureau of Standards, V. 19, 1923, p. 113 to 129.

Table I — Atomic Properties of Molybdenum

Property	Value	Notes and References
Atomic number	42	
Valence	2, 3, 4, 5, 6	
Isotopes[81]		
Stable	92, 94, 95, 96, 97, 98, 100	
Artificial (radioactive)	91, 93, 99, 101, 102, 105	
Atomic weight	95.95	1942, International[3]
Atomic radius (in metallic state)	1.39 Å	Face-centered cubic, coordination number 12[34]
	1.36 Å	Body-centered cubic, coordination number 8[34]
Ionic radius	0.68 Å	Tetravalent ion[35]
	0.62 Å	Hexavalent ion[36]
Atomic volume	9.42 cu.cm. per gram atom	Reference 37
Ionization potential	Mo^{+}: 7.35 volts	References 3 and 38
	Mo^{5+}: 60.8 volts	Reference 3
Positive ion	8.6 volts	Reference 41
Work function	3.48 ± 0.07 electron volts	From slope of thermionic emission vs. temperature curve[39]
	4.15 ± 0.02 electron volts	From thoroughly outgassed Mo; photoelectric effect[40]

As one consequence of the history of the development of the metal from differing points of view, the recorded data are quite scattered. It will, therefore, be helpful in obtaining an understanding of the technical status of molybdenum to summarize, in one convenient source, present knowledge of the properties.

Those physical properties of molybdenum which have been fairly well established and can be simply expressed are presented in Table I and in the data sheets, pages 80-B and 92.

Other properties, more difficult to define and interpret, are discussed under separate headings in the text which follows. Occasionally an attempt will be made to interpret the older data in the light of more recent experience.

Attention is called to the high Young's modulus, and high thermal conductivity, and to the low thermal coefficient of expansion (only osmium and tungsten have lower coefficients for room temperature).

Diffusion Coefficients for molybdenum in solids are known for only two alloying metals. Ham[65] has determined them in both alpha and gamma iron. He found that the diffusion coefficient D is related to the temperature by the equation

$D = Ae^{-Q/RT}$ sq.cm. per sec.

This is the Arrhenius equation, applicable to many rate processes. In the above equation, A is a constant, Q is a constant expressing the energy of activation of the diffusion process, R is the gas constant, and T is the absolute temperature.

For molybdenum in alpha iron, A = 3.467 and Q = 57,000. For molybdenum in gamma iron, A = 0.068 and Q = 59,000.

Barrer[66] has reviewed the data on the diffusion of molybdenum in tungsten, and reports for polycrystalline tungsten, A = 0.005 and Q = 80,500. For single-crystal tungsten, A = 0.00063 and Q = 80,500.

Nelting[67] measured the diffusion coefficient of thorium in molybdenum at 1700° K. as 2.3×10^{-9} sq.cm. per sec., and stated it was in good agreement with Dushman's value. Smithells[68] gives the rate of diffusion of hydrogen at 760-mm. pressure through a 1-mm. molybdenum sheet as 2×10^{-6} cc. per sq.cm. per sec. at 0° C., 5×10^{-6} at 500° C. and 4×10^{-5} at 1000° C.

CRYSTAL STRUCTURE

At room temperature molybdenum is body-centered cubic,[42] and it appears probable, from thermal expansion measurements,[43] that this

39. "The Photoelectric and Thermionic Properties of Molybdenum", by Miles J. Martin, *Physical Review*, V. 33, 1929, p. 991 to 997.

40. "The Thermionic and Photoelectric Work Functions of Molybdenum", by L. A. DuBridge and W. W. Roehr, *Physical Review*, V. 42, 1932, p. 52 to 57.

41. "Positive and Negative Thermionic Emission from Molybdenum", by R. W. Wright, *Physical Review*, V. 60, 1941, p. 465.

42. "X-Ray Crystal Analyses of Thirteen Common Metals", by A. W. Hull, *Physical Review*, V. 17, 1921, p. 571 to 588.

43. "Physical Properties of Well Seasoned Molybdenum and Tantalum as a Function of Temperature", by A. G. Worthing, *Physical Review*, V. 28, p. 190.

44. "The Accurate Evaluation of Lattice Spacings from Back-Reflection Powder Photographs", by S. S. Lu and Y. L. Chang, *Proceedings* of the Physical Society, London, V. 53, 1941, p. 517 to 528.

45. "The Rates of Evaporation and the Vapor Pressures of Tungsten, Molybdenum, Platinum, Nickel, Iron, Copper, and Silver", by H. A. Jones, I. Langmuir and G. M. J. Mackay, *Physical Review*, V. 30, 1927, p. 201 to 214.

Tensile Properties of Arc-Cast Molybdenum[37]

By Climax Molybdenum Co.

Tensile Properties and Hardness at Room Temperature

Annealing Temperature	Yield Point, Psi.	Tensile Strength, Psi.	Elongation	Reduction of Area	V.P.N.
Arc-Cast, Hot Rolled to ½-In. Diameter Bars					
Hot Rolled	99,800	100,100	32%	60.9%	255
1700° F.	—	91,700	39	59.2	—
1900	84,700	90,600	41	65.7	—
2100	54,100	73,100	53	64.2	187
2200	50,100	73,600	55	55.6	187

Test specimens, ¼-in. diameter; gage length, 1 in.; strain rate, 60% per hr.

Directional Properties at Room Temperature
(Arc-Cast, Hot Rolled, Annealed)

No.*	Direction†	Yield Point, Psi.	Tensile Strength, Psi.	Elongation	180° Bend Over T‡	
					Cold	Hot
0.050-In. Sheet, Annealed at 1850° F.						
SR-2	0	101,700	106,300	22	OK	
	90°	116,300	117,200	18	NG	
	45°				OK	
CR-2	0	102,800	107,800	22	OK	
	90°	109,600	110,900	14	NG	OK
	45°				OK	
0.020-In. Sheet, Annealed at 1800° F.						
SR-1	0	99,500	105,400	12	NG	OK
	90°	112,900	115,400	8	NG	OK
	45°				NG	OK
CR-1	0	104,700	111,400	14	OK	OK
	90°	121,600	122,000	8	NG	OK
	45°				NG	OK
SR-2	0	103,600	109,000	11	NG	OK
	90°	114,900	117,300	13	NG	OK
	45°				NG	OK
CR-2	0	108,900	114,100	14	OK	OK
	90°	123,500	125,100	12	NG	OK
	45°				NG	OK
0.013-In. Sheet, Annealed at 1800° F.						
SR-1	0	102,400	116,500	14	OK	
	90°	116,000	118,400	8	NG	OK
	45°				OK	
CR-1	0	106,400	110,100	11	OK	
	90°	107,000	108,500	10	NG	OK
	45°				OK	
SR-2	0	108,300	112,700	14	OK	
	90°		124,000		NG	OK
CR-2	0	107,000	112,500	10	OK	
	90°	120,000	121,000		NG	OK

*SR, straight rolled; CR, cross rolled. †Direction of the test bar in relation to final rolling. ‡Thickness.

Elastic Constants at Elevated Temperatures*

Testing Temperature	Young's Modulus, Million Psi.	Modulus of Rigidity, Million Psi.	Poisson's Ratio	Young's Modulus† (Koster)
Metal From Powder Process				
80° F.	45.2	17.3	0.307	47.75
250	44.9	17.2	0.308	47.30
400	44.2	16.9	0.305	46.75
500	44.2	16.9	0.305	46.40
600	43.7	16.8	0.307	46.0
700	43.5	16.7	0.305	45.6
800	43.2	16.5	0.307	45.1
900	42.9	16.3	0.307	44.6
1100	42.0	16.0	0.312	43.8
Arc-Cast, Hot Rolled to ½-In. Diameter Bars				
80	46.0	17.4	0.324	
280	44.7	16.9	0.330	
500	43.2	16.4	0.319	
725	42.7	16.3	0.317	
1175	41.0	15.6	0.314	
1400	39.9	15.1	0.321	
1600	39.9	15.1	0.321	

*The possible error is about 2% for the moduli and 4% for Poisson's ratio. †Dynamic modulus, measured by the tuning-fork method.

Directional Properties of Cold Rolled Sheet at Room Temperature
(Arc-Cast, Cold Rolled From 0.052 to 0.020 In.)

Annealing Temperature	Yield Point	Tensile Strength	Elongation
Longitudinal			
Cold Rolled	151,800 psi.	154,300 psi.	5%
1600° F.	126,500	131,500	12
1700	121,500	124,500	10
1800	111,000	117,300	13
1900	98,000	105,500	17
2000	74,400	88,800	29
2100	73,100	91,300	28
2200	75,500	90,600	26
2300	81,800	88,400	26
2400	75,400	78,800	39
Transverse			
1600° F.	130,200	132,100	3%
1700	120,900	120,900	2
1800	—	123,400	2
1900	113,700	114,700	8
2000	81,200	93,500	17
2100	86,700	91,500	16
2200	82,800	91,100	17
2300	55,000	89,400	16
2400	76,800	83,200	22

Tested in 1-in. gage length, ½ in. wide.

Tensile Properties at Elevated Temperatures

Testing Temperature	Condition	Tensile Strength, Psi.	0.2% Yield Strength	Proportional Limit	Elongation in 2 In.	Reduction of Area
Arc Cast, Hot Rolled to ⅞-In. Diameter Bars						
80° F.	As rolled	95,140	—	—	3%	2%
	Stress relieved	91,000	84,850	—	10	9
	Recrystallized	67,600	63,500	—	46	35
1600	As rolled	61,400	50,100	26,000	18	72
	Stress relieved	50,600	44,500	21,500	22	81
	Recrystallized	34,400	11,600	3,500	46	84
1800	As rolled	49,900	40,500	23,000	19	81
	Stress relieved	40,500	35,600	22,500	32	81
	Recrystallized	29,000	10,500	5,700	49	75
1950	As rolled	38,000	31,600	24,000	29	83
	Stress relieved	31,400	22,800	16,500	36	84
	Recrystallized	21,500	8,550	4,100	35	52

NOTES: The test bars, which were 0.505-in. diameter, were sprayed with aluminum to prevent oxidation while testing at elevated temperatures. Except where noted, the test bars were brought to temperature with the furnace and held for 20 min. before testing. They were loaded at the rate of 1000 psi. per min. The hot rolled material had been annealed at 1800° F. for 20 min. and then machine straightened while warm. The best stress relieving temperature, on the basis of combined tensile strength and ductility, was 1850° F. A satisfactory temperature to recrystallize the as-rolled material was 2250° F.

structure is retained to 2125° C. At 20° C. the lattice constant is 3.1403 KX units ± 0.00006, as determined by Lu and Chang[44] on Hilger molybdenum by the back reflection, powder method.

Lattice Deformation in molybdenum caused by cold working was studied by Hengstenbert and Mark.[60] Its effect on the intensity ratio of two lines with different deflection angles from the planes (200) and (400) leads to an estimate that the deviations of the atoms from the normal position in the undistorted lattice are one fiftieth of the interplanar spacing.

Single Crystal Properties — Single crystals of molybdenum have been prepared from wires by Andrade,[56] and crystals approximately a millimeter in diameter and a few centimeters long have been observed in large castings.

Tsien and Chow[70] determined the slip planes and slip directions in single crystals by Laué photographs. The slip plane at 20 and at 300° C. is (112), but at 1000° C. it is (110). The slip direction is [111] at each of the three temperatures investigated.* They noted that the lower the temperature, the less slip per slip plane, and the closer the slip planes to each other.

Elastic moduli for single crystals of molybdenum have not been measured. Druyvesteyn,[71] by computation, found that the ratio of the elastic modulus in the direction [111] to that in the direction [100] is 0.81, and stated that this is the first metal for which this ratio is found to be less than 1.

Preferred Orientations observed after rolling, drawing, and annealing are, in general, typical of those for other metals with body-centered cubic space lattices.

In drawing molybdenum wire, the crystals gradually become oriented to positions in which a face diagonal of the unit cell is parallel to the axis of the wire. The direction normal to this face has random orientation. The wire is then said to have a [110] texture.[72, 73, 63]

According to Jeffries[73] and Goss,[74] cold rolling of molybdenum sheet gradually brings the (100) planes into the plane of the sheet, with the [110] direction parallel to the rolling direction. It was noted by Jeffries and by Fujiwara[75] that there were some deviations from these orientations. Jeffries reported deviations in the (110) directions of about 10° from the rolling direction, and the (100) planes about 13° from the plane of rolling.

Ransley and Rooksby[28] conclude, from their X-ray examination of molybdenum sheet rolled in one direction, that a set of (110) planes is perpendicular to the direction of rolling, but that there is a considerable spread around the rolling direction. The (100) [011] fully oriented state is apparently not attained until the sheet is cross rolled.

Custers and Riemersma,[76] who were the first to prepare pole figures of rolled molybdenum, believe that earlier authors described the rolling textures in an oversimplified manner. They interpret their results as meaning that straight-rolled molybdenum has the (100) [011] texture but that, after cross rolling, there exists also "a second texture which is rotary symmetrical around the normal to the rolling plane, and which has a (111) plane parallel to this plane". They also found cross-rolled molybdenum, recrystallized at 1180° C. for 10 min., retains only the (100) [110] orientation. Coarse grains of random orientation result from recrystallization

*Since some doubts have been expressed concerning these results, a re-investigation of the slip system of molybdenum is in progress at the Johns Hopkins University under the sponsorship of the Office of Naval Research.

46. "The True Temperature Scale at Incandescence and the Melting Point of Molybdenum", by A. G. Worthing, *Journal* of the Franklin Institute, V. 199, p. 549.

47. "The Temperature Scale and the Melting Point of Molybdenum", by A. G. Worthing, *Physical Review*, V. 25, 1925, p. 846 to 857.

48. "Elmet Tungsten and Molybdenum", North American Philips Co., New York.

49. "Thermal Expansion of Molybdenum", by P. Hidnert and W. B. Gero, Scientific Papers of the Bureau of Standards, V. 19, 1924, p. 429 to 444.

50. "On the Thermal Conductivity of Some Metal Wires", by W. G. Kannuluik, *Proceedings* of the Royal Society, 1931, p. 320.

51. "The Thermal and Electrical Conductivities of Several Metals Between −183° C. and 100° C.", by W. G. Kannuluik, *Proceedings* of the Royal Society, V. 141, 1933, p. 159 to 168.

52. "Thermal Conductivities of Tungsten and Molybdenum at Incandescent Temperatures", by Robert H. Osborn, *Journal* of the Optical Society of America, V. 31, 1941, p. 428 to 432.

53. "Some Properties of High-Purity Sintered Wrought Molybdenum Metal at Temperatures Up to 2400° F.", by R. A. Long, K. C. Dike and H. R. Bear, National Advisory Committee for Aeronautics, Technical Note 2319, March 1951.

54. "Metals Handbook", 1948 Edition, American Society for Metals, Cleveland, p. 1139.

55. "Technical Data Bulletin", Fansteel Metallurgical Corp., 1948.

56. "Preparation of Single Crystal Wires of Metals of High Melting Point", by E. N. da. C. Andrade, *Proceedings* of the Royal Society, V. 163, 1937, p. 16 to 18.

57. "Tensile Properties of Arc-Cast Molybdenum", Climax Molybdenum Co., *Metal Progress*, V. 58, August 1950, p. 200-B.

Fig. 6—Unusually High Reflectivity of Bright-Finish Molybdenum Sheet May Even Be Further Enhanced by Polishing. (Fansteel Metallurgical Corp.)

at 1280° C. Thus, the texture of straight-rolled molybdenum is identical to that of straight-rolled iron.

By means of Laué photographs, Fujiwara[77] studied the orientations in molybdenum films deposited from vapor in a vacuum. He found that such crystals formed with the (110) plane nearly parallel to the surface. Landau[78] reported a [110] fiber texture for films formed by evaporation, with the fiber axis normal to the film.

The [110] textures in molybdenum wire are retained upon recrystallization,[73] but a [100] recrystallization[79] texture has also been reported.

Recrystallization — The 1948 edition of Metals Handbook gives the lowest temperature of recrystallization for molybdenum as 1650° F. More recent observations during creep-rupture

Recrystallization at High Temperature

tests made at Battelle indicate that some recrystallization can occur under the influence of stress as low as 1600° F. The normally fibrous structure of molybdenum obtained on hot rolling or drawing is usually retained after annealing for approximately 15 min. at 2200° F. When worked molybdenum is annealed above 2900° F., large, equiaxed grains are formed and a structure brittle at room temperature generally results.[28]

Kioka[29] states that cold rolled sheet molybdenum (0.10 mm. thick) recrystallizes within 5 min. at 1030° C. (1885° F.), and that when recrystallization occurs at 1090° C. (2000° F.) it is accompanied by a marked drop in ductility.

There would probably be no inconsistency in these data if the effects of time, temperature, stress at temperature, purity, and amount of cold work were fully accounted for.

Heat of Evaporation — Langmuir and Mackay,[80] from their studies of the high-temperature properties of molybdenum, believe that the value of the latent heat of evaporation of molybdenum as a function of temperature is best represented as follows:

$$\lambda = \lambda_o - 2.5T$$

where T is temperature in degrees K. and λ_o was experimentally determined to be 177,000 gram-calories per mole.

Thermal Expansion — Hidnert and Gero[40] found that grain size of the parent molybdenum powder and heat treatment of the swaged bars affect the thermal expansion of molybdenum. For samples prepared from fine-grained molybdenum powder, the average coefficients of expansion between 25 and 500° C. vary from 5.4×10^{-6} to 5.8×10^{-6} per °C. For the samples prepared from coarse-grained powder, the coefficients vary from 4.7×10^{-6} to 5.7×10^{-6}. Annealed samples had somewhat larger coefficients than cold-worked samples, as shown in the graph in the data sheet, page 80-B.

A thermal-expansion curve for molybdenum was determined by Worthing.[43] There are no

58. "High-Speed Steel", by M. A. Grossmann and E. C. Bain, John Wiley & Sons, Inc., p. 83.

59. Fifth Quarterly Report on Contract No. N9onr 82100, Battelle Memorial Institute to Office of Naval Research, Aug. 1, 1950.

60. "The Effect of Temperature on the Modulus of Elasticity of Pure Metals", by Werner Köster, *Zeitschrift für Metallkunde*, V. 39, 1948, p. 1 to 9.

61. "Gas Turbine Alloys, Ten Years Later", by Howard Scott, *Metal Progress*, V. 58, October 1950, p. 503 to 511.

62. "Electrical Resistance and Thermoelectric Power of Transition Metals", by H. H. Potter, *Proceedings* of the Physical Society, V. 53, 1941, p. 695 to 705.

63. "Structure of Metals", by C. S. Barrett, McGraw-Hill Book Co., New York, 1943.

64. "Heat Transfer Notes for Electrical Engineers", by A. D. Moore, George Wahr, Publisher, Ann Arbor, Mich., 1940.

65. "The Rate of Diffusion of Molybdenum in Austenite and in Ferrite", by J. L. Ham, *Transactions* of the American Society for Metals, V. 35, 1945, p. 331 to 361.

66. "Diffusion in and Through Solids", by Richard M. Barrer, The Macmillan Co., New York, 1941.

Excellent Creep-Rupture Properties

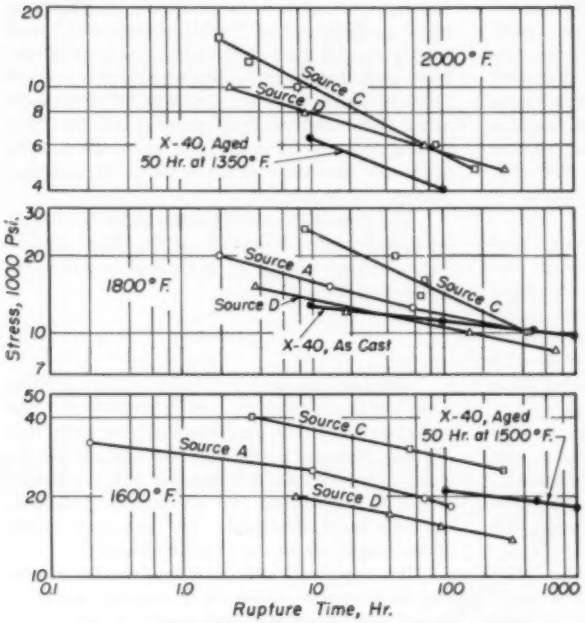


Fig. 7 — Creep-Rupture Curves for Recrystallized Molybdenum From Three Different Sources at 1600, 1800 and 2000° F., in Comparison With Commercial Alloy X-40 (Cobalt-Base) by Haynes Stellite Co.

discontinuities up to the highest temperature investigated, about 2425° K. Worthing's measurements were made on the purest molybdenum he was able to obtain, and correspond to the following equation:

$$L/L_{300} = 5.00 \times 10^{-6}(T-300) + 10.5 \times 10^{-10}(T-300)^2.$$

Creep-Rupture Properties — Preliminary data only are available. The values vary widely, depending on the source of the metal, and the significant variables have not been identified. The data must, therefore, be considered as indicative only of the order of magnitude. They do, however, permit the conclusion that, above about 1800° F., molybdenum has a higher load-carrying capacity than heat resistant metals commercially accepted.

The results of creep-rupture tests at 1600, 1800, and 2000° F., made in vacuum by Cross and co-workers at Battelle Memorial Institute in a program of research on molybdenum sponsored by the Office of Naval Research, are presented in Fig. 7. A cobalt-base alloy, representative of the best engineering alloys of today, has also been plotted.

Directionality — Molybdenum exhibits directionality of properties after cold work. This is due, in part at least, to preferred orientation of the individual crystals. Ransley and Rooksby[28] have noted that molybdenum sheet, when

67. "Molybdenum-Thorium", by H. Nelting, *Zeitschrift für Physik*, V. 115, 1940, p. 469 to 480.

68. "Permeability of Metals to Hydrogen", by C. J. Smithells, *Nature*, V. 139, 1937, p. 1113.

69. "An X-Ray Method for the Detection of Lattice Distortion in Metals", by J. Hengstenberg and H. Mark, *Naturwiss.*, V. 17, 1929, p. 443.

70. "Glide of Single Crystals of Molybdenum", by L. C. Tsien and Y. S. Chow, *Proceedings* of the Royal Society, V. 163, 1937, p. 19 to 28.

71. "Elastic Anisotropy of Molybdenum", by M. J. Druyvesteyn, *Physica*, V. 8, 1941, p. 439 to 448.

72. "Fibrous Structure of Hard-Drawn Metals", by M. Ettisch, M. Polanyi and K. Weissenberg, *Zeitschrift für Physik*, V. 99, 1921, p. 332 to 337.

73. "The Trend in the Science of Metals", by Z. Jeffries, *Transactions* of the American Institute of Mining and Metallurgical Engineers, V. 70, 1924, p. 303 to 327.

74. "Application of X-Rays to the Study of Plastic Deformation in Steel Wires and Molybdenum Ribbon", by Norman P. Goss, *Transactions* of the American Society for Metals, V. 17, 1930, p. 241 to 261.

75. "Arrangement of Micro-Crystals in Rolled Foils of Tungsten and Molybdenum", by Takeo Fujiwara, *Proceedings* of the World Engineering Congress, Tokyo (1929), V. 36, 1931, p. 179 to 182.

76. "The Textures of Straight-Rolled and of Cross-Rolled Molybdenum", by J. F. H. Custers and J. C. Riemersma, *Physica*, V. 12, July 1946, p. 195 to 208.

77. "Arrangement of the Micro-crystals in the Film of Molybdenum Obtained by Deposition", by Takeo Fujiwara, Member of the College of Science, Kyoto Imperial University, Series A, V. A15, 1932, p. 31 to 33.

78. "A Correlated Abstract on the Use of Electron Diffraction in Studying Corrosion", by I. R. Landau, *Metals and Alloys*, V. 9, 1938, p. 73 to 77, 100 to 103.

79. "The Effect of Heat Treatment on the Crystal Arrangement of Tungsten and Molybdenum Wire", by Takeo Fujiwara, *Proceedings* of the World Engineering Congress, Tokyo (1929), V. 36, 1931, p. 171 to 178.

80. "The Vapor Pressure of the Metals Platinum and Molybdenum", by I. Langmuir and G. M. J. Mackay, *Physical Review*, V. 4, 1914, p. 377 to 386.

81. "Chart of the Nuclides", December 1949, General Electric Research Laboratory.

cross rolled, tends to fracture along lines at 45° to the direction of rolling. They have termed this "45° brittleness", and, from their X-ray data on preferred orientation, conclude that the (100) planes are cleavage planes for molybdenum. They used a standard Jenkins' bend-test machine in which a strip of metal about ½ in. wide is bent backward and forward through 180° over a pair of steel jaws ground to 1-mm. radius. A complete bend is specified as 180°.

In their tests, Ransley and Rooksby used sheet 0.1 mm. in thickness. The results for straight-rolled molybdenum, plotted as the number of bends versus the angle of test piece to the direction of rolling, show that the number of bends decreases from about 27 at 0° to about 9 at 90°. Similar data for cross-rolled sheet show a minimum in the number of bends at 45°.

Marden and Wroughton[30] state that the ultimate tensile strength of sheet molybdenum (made by powder metallurgy) in the transverse direction is as high as in the longitudinal direction, but the yield strength is lower in the transverse direction.

A different relation seems to hold for sheet made from arc-cast molybdenum. For such sheet, cold rolled from 0.052 to 0.020 in. and annealed at 2100° F., the transverse yield strength was about 87,000 psi. (with 16% elongation), while the longitudinal yield strength was about 73,000 psi. (with 28% elongation). The tensile strength was, in both cases, about 91,000 psi.[57]

Density of molybdenum has been measured in all of the stages in its preparation by the powder-metallurgy method. Marden and Wroughton[30] state: "Commercial molybdenum has a particle size of 1 or 2 microns and, when lightly tapped in a cylinder or glass graduate, has a bulk density of 3. The density of a pressed billet is normally 6 and of heat treated ingots about 9.8. During the working of the heat treated ingot to form sheet or wire, the density gradually increases until a value of approximately 10.3 is reached."

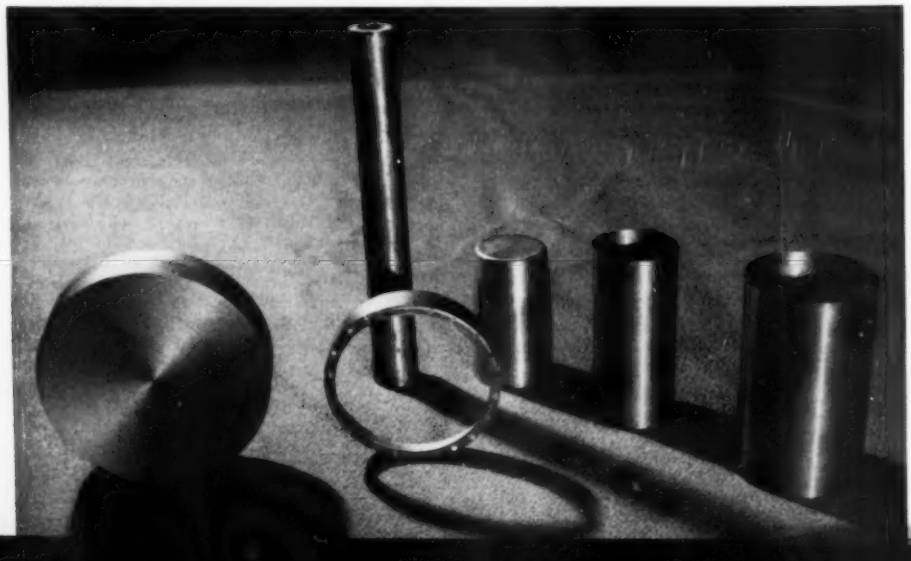
The density of molybdenum at 20° C. is 10.35 computed from Lu and Chang's[44] lattice parameter, an atomic weight of 95.95, and an Avogadro number of 6.023×10^{23}.

SUMMARY

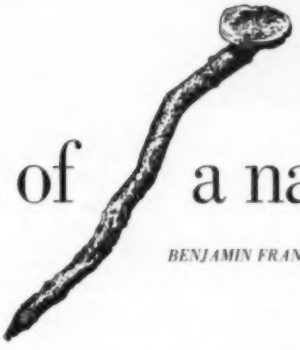
Molybdenum is one of the very promising materials for engineering use above 1600° F. The principal favorable properties of the metal are its high melting point, high Young's modulus, high thermal conductivity, and low coefficient of thermal expansion. Of the refractory metals, it is the most abundant. The principal mines of the world are in the Western States.

The important unfavorable properties are its low resistance to oxidation at elevated temperatures, and its occasional brittle mechanical behavior. Good progress has been made in overcoming these disadvantages. It is realistic to expect that they will not be permanent obstacles to the general use of molybdenum as a heat resistant material of construction.

Fig. 8 — Molybdenum Is Available for Structural and Mechanical Parts in Pieces of Large Size and Complex Shape — Forgings, Seamless Tube, Spun or Stamped Sheet, Riveted or Welded Items. (Courtesy Westinghouse Electric Corp.)



"For the want of a nail the shoe was lost,
For the want of a shoe the horse was lost,
For the want of a horse the rider was lost,
For the want of a rider the battle was lost,
For the want of a battle the Kingdom was lost . . .

and all for want of  a nail"

BENJAMIN FRANKLIN, "Poor Richard," 1758

The fate of nations often hangs on little things. Take this rusty old nail. It symbolizes thousands of tons of worn-out machines and broken parts lying useless in our plants, factories, farms, and homes—scrap steel desperately needed today by our steel mills.

You can help make this nail, and all the other scrap you can collect, go to work again . . . in new steel for ships, tanks, and guns required for defense purposes.

So survey your plant now for every last bit of scrap. Then get it to your scrap dealer promptly. This will not only help assure the nation of the arms needed to preserve our freedom, but it will also mean more steel for your own products tomorrow.

ELECTRO METALLURGICAL COMPANY, a Division of Union Carbide and Carbon Corporation.

Personal Mention

C. Stewart Parsons

C. STEWART PARSONS, director of the Mines Branch, Department of Mines and Technical Surveys, Canada, recently received the Inco Platinum Medal for his "meritorious contribution of outstanding importance to the mining and metallurgical industry" at the annual meeting of the Canadian Institute of Mining and Metallurgy. Mining caught his fancy early. The mine was the center of his home town, Springhill, Nova Scotia, and his father, N. F. C. Parsons, was a mining engineer and a general manager of Canadian Iron Corp. By the time he was 14 he was working underground during vacations as chainman and surveyor's helper. He attended King's College, Windsor, N. S., and received his mining engineering degree from Queen's University in 1913. He joined the Government Service a year later and has remained there ever since except for a three-year period during which he was superintendent of the American Graphite Co., Graphite, N. Y., and mining engineer for the Mining Corp. of Canada. In 1936 Mr. Parsons was appointed chief of the Metallic Minerals Division, Bureau of Mines. In both the peacetime expansion in mining and during the six years of war, his technical and administrative abilities were called into full play, and his contributions to the war effort won him the Coronation Medal and the O.B.E. (Civil Division). In 1946 he was made chief of the Bureau, and he was appointed director of the Mines Branch when the new Department of Mines and Technical Surveys was created in 1950. He is recognized as one of Canada's most distinguished researchers in his field and he was a pioneer in developing the flotation process for the treatment of ores. At present he is introducing the application of radioactive tracers to studies of ore dressing methods.

George Bramson, who graduated from Lafayette College in June 1951, has accepted a position as material planner with the engineering department of Picatinny Arsenal, Dover, N. J.

Alfred C. Schwarz, who was formerly employed in the research laboratories of the Texas Co., Beacon, N. Y., has recently accepted a position as mechanical engineer with Sandia Corp., Albuquerque, N. M.

Howard A. Hoover has been employed as a metallurgist with John A. Roebling's Sons Co., Trenton, N. J., in the department of research and development, since graduating from Temple University.

W. R. Ellis has recently accepted a position as engineer in training with the Steel Co. of Canada, Hamilton Works, Hamilton, Ont., Canada.

William J. Baumgarten, secretary-treasurer of the Mahoning Valley Chapter, has been transferred to the alloy unit, United States Steel Co., Pittsburgh, as a metallurgist.

Stan W. Moulding, Sr., has just been appointed chief engineer and metallurgist for the American Enterprises Co., New York, importer-exporter of ferrous and nonferrous metals.

Truman J. Hammel, formerly in the research engineering division of the Chain Belt Co., Milwaukee, has recently been appointed district sales engineer in the Kansas City office.

Clarence H. Lorig

CLARENCE H. LORIG, assistant director of Battelle Memorial Institute, Columbus, Ohio, and recent recipient of a distinguished service citation for accomplishments in the metallurgical engineering field from the University of Wisconsin, has made outstanding contributions to the foundry industry and stimulated and guided much research in process metallurgy. He is credited with research leading to 11 patents on alloys and metallurgical processes, and recent experience has associated him closely with the development of many of the important refractory metals such as tungsten, molybdenum, titanium, zirconium and chromium. Undergraduate and graduate studies in mining and metallurgy at the University of Wisconsin set the foundation for Dr. Lorig's career, and a variety of early industrial experience gave him a practical turn of mind which he has used to good advantage in applying science to the problems of industry for the past 20 years at Battelle's industrial research laboratory. Dr. Lorig is active in the work of the American Society for Metals, in the American Institute of Mining and Metallurgical Engineers, the American Foundrymen's Society, and the Society of Automotive Engineers. In 1950 the American Foundrymen's Society awarded him the Joseph S. Seaman Gold Medal for distinction in metallurgical research. He is the author of more than 60 articles and papers on metals and alloys which have been published in scientific, technical and trade journals.

Once Again—

HERCULOY

is Chosen for Hot Water Storage Generators

WELDING HERCULOY *plates into a hot water storage generator for the new Veterans' Hospital in Boston.*

ROLLING HERCULOY *plates into cylindrical form for the tanks. Photos from The Patterson-Kelley Co., Inc., East Stroudsburg, Pa.*

HERCULOY is Revere's Copper-Silicon Bronze, which has the corrosion resistance of copper plus the strength of mild steel. It is therefore ideal for hot water tanks, among many other applications. Much has gone into domestic water heaters, but these are far outstripped in size by a number of large tanks fabricated of Herculoy by The Patterson-Kelley Co., Inc., East Stroudsburg, Pa., for the new Veterans' Hospital in Boston. The water is heated by steam passing through bundles of Revere Phosphorized Copper Tube. Inlet and outlet flanges are Herculoy, made from heavy gauge extruded shells, which offer economies over the alternative method of cupping them out of plate.

Patterson-Kelley weld all these large storage heaters, using Heliarc. Easy weldability is another important quality of Herculoy. Golden beauty is also a feature, and the size and beauty of these tanks created a great deal of comment while they were being trucked to the hospital. . . . Remember Herculoy's qualities: corrosion resistance of copper, strength of mild steel, easy weldability and formability, and beauty. Remember other applications besides tanks, such as: vats, screens, filters, ducts, fire extinguishers, chemical and marine construction.

REVERE 150th YEAR OF SERVICE TO AMERICA

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

230 Park Avenue, New York 17, N. Y.

* * *

Mills: Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y.— Sales Offices in Principal Cities, Distributors Everywhere

SEE "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

Personals

Hubert J. Pessl has resigned as assistant professor of physical metallurgy at the State College of Washington to join Lake Erie Engineering Corp., Buffalo, N. Y., as chief metallurgist. Dr. Pessl, who received his Sc.D. degree from the State College of Mining and Metallurgy, Leoben, Austria, in 1933, has had extensive metallurgical engineering and research experience in this country and abroad.

Gilbert Soler has been appointed supervisor of research associates in the research and technology departments of the United States Steel Co., Pittsburgh. Mr. Soler was vice-president in charge of manufacturing operations at Atlas Steels Ltd., Welland, Ont., before joining United States Steel Co. in February 1951.

Harold P. Halverstroh, Jr., who graduated from Purdue University in January, is now working at Moraine Products Div., General Motors Corp., Dayton, Ohio.

MILNE'S COMPLETE LINE OF HOLLOW AND SOLID TOOL STEELS HAVE OVERALL COLOR IDENTIFICATION THAT SIMPLIFIES INVENTORY CONTROL

MILNE'S TOOL STEELS ARE "UNFORGETABLE" BECAUSE THEY'RE KOLORKOTED – The entire length of the steel is spray painted an identifying color for permanent, quick-as-a-glance identification. Each piece of Milne tool steel keeps on telling you and your employees what it is. Milne's steels are practically confusion-proof.

MILNE'S TOOL STEELS ARE "UNFORGETABLE" BECAUSE EACH HAS A MATCHING HEAT TREAT CARD–With every shipment goes a heat treatment card of a color that matches the steel. Gives complete heat treat instructions. Eliminates costly wrong guesses.

With Milne Tool Steels you *can't forget what you get or how to treat it as long as you have it.*

The tool steel selector shown above helps you pick the proper Milne steel and gives you the complete story on it. Ask any Milne office for your copy, today.

SALES OFFICES & WAREHOUSES
NEW YORK 14, N.Y. Tel. Watkins 4-3830
CHICAGO 7, ILL. Tel. MOnroe 6-2996
BOSTON 27, MASS. Tel. SOuth 8-5305
PITTSBURGH 12, PA. Allegheny 1-6152
PHILA. 6, PA. LOmbard 3-3992
N. BRITAIN, CONN. Tel. 3-4183
CLEVELAND 5, O. BRoadway 1-3035
SALES OFFICES
ROCHESTER 4, N.Y. Tel. Baker 1963

ST. LOUIS, MO. Tel. LUcas 1926
SPRINGFIELD 3, MASS. Tel. 6-7593
BRIDGEPORT 3, CONN. Bridgeport 5-0159
DAYTON 2, OHIO Tel. ADams 9063
ATLANTA, GA. Tel. Emerson 3716
PACIFIC COAST
Office & Warehouse
SAN FRANCISCO, CAL. Tel. SUtter 1-8200

For Southern Calif.
TAYLER-SPOTSWOOD OF CAL.
Tel. LOgan 5-7461
For Pacific Northwest
PACIFIC MACH. & TOOL STEEL CO.
Portland 14, Oregon
Tel. East 2148

SOUTHWEST
VINSON SUPPLY CO.
Dallas, Texas

CANADA
SANDERSON-NEWBOULD, LTD.
Montreal Toronto

AM-4

A. MILNE & CO.
743 WASHINGTON ST. NEW YORK 14, N.Y.

Tugrul Aktutay has been working in the research and development department of Inland Steel Co., East Chicago, Ind., as a research metallurgist, since his graduation from University of Wisconsin last June.

William K. Heid, formerly with Pontiac Motor Foundry, Pontiac, Mich., has become plant metallurgist for the Allyne-Ryan Foundry Co., Cleveland.

L. C. Berkey, formerly district sales manager of the Chicago office of Jones & Laughlin Steel Corp., has been transferred to the Detroit office in the same capacity.

Norman P. Pinto, formerly senior engineer with Sylvania Electric Products Inc., New York, has taken a position as research metallurgist at Rem-Cru Titanium Inc., Bridgeport, Conn.

A. D. Stevens has joined Kennametal, Inc., Latrobe, Pa., as a metallurgist to do product development work.

Carl I. Schweizer, formerly superintendent of the turbine forgings division of Steel Improvement & Forge Co., Cleveland, has joined the Allison Div. of General Motors Corp., Indianapolis, in the material procurement division of aircraft engine operations.

O. S. Hukku has been employed as a graduate apprentice at the Tate Iron & Steel Co., Ltd., Jamshedpur, India, since receiving his degree in metallurgy in 1949.

A. F. Mackel is now working for the General Electric Co. under the direction of the Atomic Energy Commission, Richland, Wash.

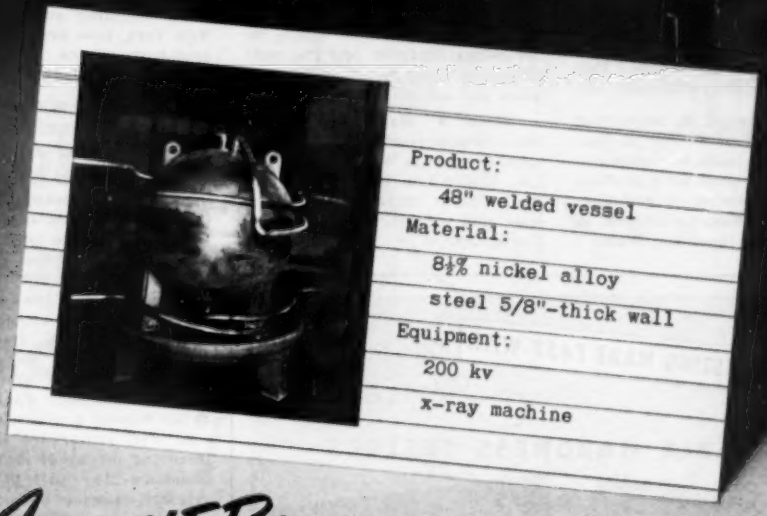
P. A. Haythorne, formerly in charge of metallurgical research at Lockheed Aircraft Corp., Burbank, Calif., has recently joined Douglas Aircraft Co. as chief metallurgical engineer of the Tulsa, Okla., division.

Yeshwant P. Telang has been employed at Ford Motor Co., River Rouge Plant, Dearborn, Mich., since his graduation from University of Michigan in March.

Kenneth B. Dempsey is now employed as a research engineer in the research laboratory, National Tube Co., Pittsburgh.

J. P. Somers has been appointed assistant vice-president of the Wyckoff Steel Co. of Pittsburgh, and will be in their Philadelphia office.

WHAT'S THE RIGHT X-RAY FILM?



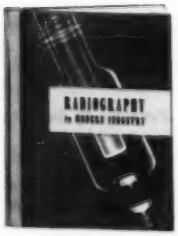
ANSWER:

KODAK INDUSTRIAL X-RAY FILM, TYPE F

This sphere was to take an important place in a new industrial process. Its work was critical. It had to be sound.

To check the welded girth seam, radiographs were made. With double metal wall thicknesses to shoot through, the radiographer used 200 kv at 10 ma for three minutes with calcium tungstate intensifying screens and Kodak Industrial X-ray Film, Type F.

With calcium tungstate screens this film provides the highest available speed and high contrast. It has wider latitude and medium speed when used direct or with lead-foil screens.



RADIOGRAPHY IN MODERN INDUSTRY

A wealth of invaluable data on radiographic principles, practice, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get your copy from your local x-ray dealer—price, $3.

A TYPE OF FILM FOR EVERY PROBLEM

To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film. These provide the means to check castings and welds efficiently and thus extend the use of both processes.

Type F—provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type A—has high contrast with time-saving speed for study of light alloys at low voltage and for examining heavy parts at 1,000 kv. Used direct or with lead-foil screens.

Type M—provides maximum radiographic sensitivity, under direct exposure or with lead-foil screens. It has extra-fine grain and, though speed is less than in Type A, it is adequate for light alloys at average kilovoltage and for much million-volt work.

Type K—has medium contrast with high speed. Designed for gamma ray and x-ray work where highest possible speed is needed at available kilovoltage without use of calcium tungstate screens.

EASTMAN KODAK COMPANY
X-ray Division · Rochester 4, N.Y.

Radiography...

another important function of photography

Kodak
TRADE-MARK

Personals

Charles H. Weber, Jr., has been made sales engineer for the New England states by Allied Metals Specialties, Inc., Baltimore, Md.

L. W. Eastwood, supervisor of nonferrous metallurgy at Battelle Memorial Institute, Columbus, since 1947, has accepted a position as assistant director of metallurgical research, Kaiser Aluminum & Chemical Corp., Spokane, Wash.

C. G. zurHorst, formerly research metallurgist of the Gulf Research & Development Co., is now associated with the Boder Scientific Co., Pittsburgh, where he serves metallurgists and the metallurgical laboratories with supplies and equipment.

Robert F. Hartmann has taken a new position as metallurgical engineer at Western Cartridge Co., East Alton, Ill. He was formerly plant metallurgist of the gear and axle division, Chrysler Corp., Detroit.

Herman D. Carus of Matthiessen & Hegeler Zinc Co., LaSalle, Ill., and **G. Howard LeFevre** of U. S. Smelting and Mining Co., New York, have been elected vice-presidents of the American Zinc Institute, New York.

A. O. Schaefer has been elected vice-president in charge of sales by the Midvale Co., Philadelphia.

The research and technology department of United States Steel Co., Pittsburgh, has announced the following changes and additions to its laboratory staff: **Dudley H. Rowland**, formerly research associate at the laboratory, has been promoted to assistant to the manager; **John G. Donelson**, formerly research associate, has been promoted to supervisor of research associates; **Paul Marshall** has become a research associate and will supervise programs involving physical metallurgy; **Shadburn Marshall**, formerly research associate on the research and development staff, has been transferred to the laboratory to supervise research programs in process metallurgy; and **Robert L. Stephenson**, formerly chief metallurgist at the company's Duquesne Works, has been appointed research associate and will supervise research concerning blast furnace development.

H. R. Butler has been employed as a junior production engineer trainee at the reduction plant of International Nickel Co. of Canada, Copper Cliff, Ont.

Lawrence A. Zeis, formerly metallurgist at Emerson Electric Co., St. Louis, is now production metallurgist for the Nordstrom Valve Div., Rockwell Manufacturing Co., Oakland, Calif.

Zygfried R. Wolanski has been employed as a metallurgist by Rotary Electric Steel Co., Detroit, since his graduation from Michigan College of Mining and Technology in March.

S. Sarker has recently joined the International Smelting and Refining Co., Tooele, Utah, as a chemist.

Oren H. Persons has been elected a vice-president of the Edgcomb Steel Co., Philadelphia.

Anthony J. Zino, Jr., formerly assistant to the president of Swan-Finch Oil Corp., New York, has been appointed domestic general sales manager of Joseph Dixon Crucible Co., Jersey City, N. J.

HARDNESS TESTING MADE EASY WITH *Ames*

PORTABLE HARDNESS TESTERS

— Hardness testing in difficult places with Ames easy-to-use Portable Tester.

— Hardness testing large sheets. Reading directly in the Rockwell Scales.

ARE TAKEN TO THE WORK
FOR QUICK, ACCURATE, SIMPLE TESTS

Hardness testing — before and after heat treating — is essential today.

Ames Portable Hardness Testers now make it practical and EASY to test for hardness at any stage of your manufacturing process. Make quick, accurate tests on the spot. No cutting off specimens. No waiting for laboratory tests. No skill is required. Anyone can operate.

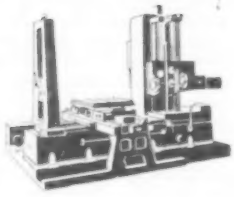
Thousands are now in use and paying for themselves, over and over again. Investigate today how Ames Hardness Testers can be quickly put to profitable use in your plant.

Send for descriptive literature.

Ames Portable Hardness Testers are light in weight, compact, accurate and comparatively inexpensive. Models from 1" to 6" capacity.

AMES PRECISION MACHINE WORKS
WALTHAM 54, MASS.

Mobilizing Machine Tools



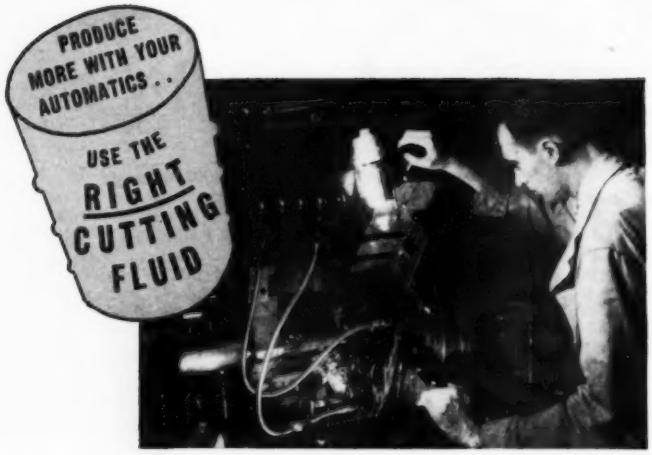
MORE OUTPUT is the nation's urgent need. Quality is wanted in quantity . . . and double-quick. So champion expediters are needed. There's an all-star team of these expediters in the complete Cities Service line of industrial lubricants for every machine tool . . . every related operation. The crack quarterback in the line-up is the Cities Service Lubrication Engineer.

Each Cities Service item is *right*, or it wouldn't be in the line. On top of full quality, Cities Service affords users the speedy convenience of one responsible, progressive source of supply.

And now when methods and products may be in line for fast changes, there's extra value in the know-how of the Cities Service Lubrication Engineer. His business is improving machine tool and shop lubrication to help you boost production. *He knows his business.* His address is CITIES SERVICE OIL COMPANY, Room 17, Sixty Wall Tower, New York City 5. Write. Or phone your nearest Cities Service office.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS



▼ **STUART'S THREDKUT 99 MORE THAN DOUBLES TOOL LIFE PER GRIND.** In threading type 310 stainless male pipe union sections on large automatics, a Milwaukee plant was getting 136 pieces per tool grind. A change to Stuart's ThredKut 99 increased this to 310 pieces per grind —and the cost was 3c less per gallon for oil.

▼ **FORM TOOL LIFE INCREASED 36% WITH STUART'S SPEEDKUT B**—on 6 spindle automatics forming and threading cut-off cap screws of SAE 1060, 10-17 Rockwell C.

▼ **4 TO 1 LESS MACHINING DOWNTIME WITH SPEEDKUT B.** After changing to this Stuart product on an automatic turning out worm gear blanks, the customer reports, ". . . machine now made available to more production within its capacity."

ARE YOU really getting the capacity that was built into your automatic screw machines? In shop after shop, Stuart oils correctly applied have upped production substantially and, as a by-product, have usually improved quality and increased tool life.

It is worth finding out what a Stuart Representative can accomplish for you. Ask to have him call and SEND FOR EDUCATIONAL LITERATURE on cutting fluids for screw machines.

D.A. Stuart Oil Co.
EST. 1865 LIMITED

2743 S. Troy St., Chicago 23, Ill.

Personals

Harry Van Osdall Churchill, who has been chief of the analytical division of Aluminum Research Laboratories and chief chemist of Aluminum Co. of America since 1919, retires from this position as of July 1. His son, John Raynor Churchill, who is well known for his spectrographic work and his membership on the editorial committee for Analytical Chemistry, will succeed him as chief of the analytical division of Aluminum Research Laboratories.

Max Hansen, author of *the* book on the constitution of binary alloys, has been named assistant chairman of the metals department of Armour Research Foundation of Illinois Institute of Technology. Dr. Hansen will continue his work in physical metallurgy in which he has established an international reputation.

Harold F. Lathrop, formerly project engineer for room air conditioners division of Philco Corp., Philadelphia, is now product engineer for cooling equipment at General Electric Co., Air Conditioning Division, Bloomfield, N. J.

R. W. Stobbs has recently resigned as chief metallurgist with Messrs. J. and H. McLaren, Ltd., to take up employment as senior research metallurgist at the David Brown Foundries Co., Sheffield, England.

James J. Miller has been employed in the special metals division of the Carboloy Co., Schenectady, N. Y., since his graduation from Rensselaer Polytechnic Institute in January.

A. S. Bain is now employed by the Atomic Energy Project, National Research Council, Chalk River, Ont., as a junior research officer.

Fred N. Durhame, who graduated from the University of British Columbia in 1950, has recently been employed by the Algoma Steel Corp., Sault Ste. Marie, Ont., Canada, and is taking their training course for junior engineers.

Jose C. Seijas is currently attached to the Naval Training Center in Catia de La Mar, Venezuela, in charge of the assembly of new power plants being installed for training purposes.

SPEED VOLUME ANNEALING OF SMALL ARMAMENT PARTS

The basket in the upper left was designed for an aircraft plant for annealing aluminum and magnesium castings. With movable sides and trays, it cuts handling time materially. The perforated pot at right was furnished a defense contractor for fast handling of small parts at a Homo furnace. Some PSC designed-for-the-job fixtures have eliminated as many as three complete handlings.

Furthermore, PSC welded alloy units save time because, being 2/3 lighter than cast equipment, they handle faster; and require less time to attain pot heat. A recent study of one customer's cycle showed a total saving of 5 hours.

Let our technical staff work with you in devising time-saving units. As pioneers of light-weight, sheet alloy, heat-treating containers and fixtures, we make available to you a wealth of designing and production know-how. We furnish equipment in any size. Send blue-prints or write as to your needs.

PSC "Light Weight"

Heat-Treating Equipment for Any Product and Any Metal

Carburizing and Annealing Boxes	Tumbling Barrels - Tanks
Baskets - Trays - Fixtures	Cyanide and Lead Pots
Muffles - Retorts - Racks	Thermocouple Protection Tubes
Annealing Covers and Tubes	Radiant Furnace Tubes and Parts
Pickling Equipment	Heat, Corrosion Resistant Tubing

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

Sphero-Conical Diamond

BRALE*

Penetrator for Hardened Steel

A. Minor load penetration

B. Major load penetration

C. Linear measurement of penetration increase which "ROCKWELL" converts to hardness reading

A Difference of only .00008"!

A difference of only .00008" in penetration ("C" above) equals one point of hardness on "ROCKWELL" scale.

Example:

"C" equals .00320" at C 60 Rockwell reading
"C" equals .00312" at C 61 Rockwell reading

Difference .00008" equals 1 point on Rockwell scale

A penetration error of 80 millionths of an inch throws hardness reading off completely. To be SURE, use only "BRALES" which have been tested and approved in WILSON'S STANDARDIZING LABORATORY.

Wilson's Diamond "BRALE" Penetrators are precision ground under high magnification to assure mathematical and microscopic accuracy. Each is standardized on many test blocks and rigidly inspected before it receives the Wilson stamp of approval. The degree of accuracy of "BRALE" Penetrators makes them highly satisfactory for research laboratory work.

Write for literature

*Trade Mark Registered

ACCO **WILSON**

MECHANICAL INSTRUMENT DIVISION
AMERICAN CHAIN & CABLE

TRADE MARK

230-F Park Avenue, New York 17, N. Y.

Personals

Wilton F. Melhorn has recently taken a position as assistant professor of metallurgy at the University of Cincinnati.

Donald E. Holstein has joined the research staff at Battelle Memorial Institute, Columbus, Ohio, as a research metallurgist.

Robert V. Cordingley, formerly employed at Youngstown Sheet & Tube Co., Indiana Harbor Works, has taken a position as chief tin mill metallurgist and inspector of the Fairless Plant of United States Steel Co., now under construction in Morrisville, Pa.

William C. Rion, Jr., formerly materials engineer for the Airtemp Div., Chrysler Corp., Dayton, Ohio, is now employed as an engineer in the materials section of the engineering service division of E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Theodore H. Heemstra has been recalled to active duty in the Army and is assigned to the Ordnance Corps, Watertown Arsenal, Watertown, Mass., as an assistant to the director of production.

Jonmore Dickason has been elected general manager of Metal Control Laboratories, Los Angeles.

Roger A. Long, formerly head of the metallurgical section, National Advisory Commission for Aeronautics, has been promoted to chief of the Metallurgical Branch.

B. F. Bennett is at present on duty as a commander, U.S.N., as repair superintendent, Ship Repair Facility, Fleet Activities, Yokosuka, Japan.

Clyde A. Rosellen has accepted a position as senior plant metallurgist at Reynolds Metals Co., Louisville, Ky. He was formerly with the department of metallurgical research at Kaiser Aluminum & Chemical Co., Spokane, Wash.

James W. Doll, formerly manager of sales of warehouse products at the steel division of Timken Roller Bearing Co., Canton, Ohio, and later vice-president and general manager of Alloy Steels, Detroit, Mich., is now president of Northwest Sales, Inc., Detroit.

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Lehigh H Shear Blades To Blame for Idle Time

The other day a Bethlehem salesman was surprised to find one of his good customers, a shop boss, in a somewhat hostile mood for no apparent reason. "You've got me in real trouble," the boss said. "Remember that Lehigh H steel you suggested we use for shear blades?"

"Why, yes, I do," admitted the salesman.

"Well, come with me," replied the customer. "I want to show you something."

They walked out in the shop where the shear blades were used to cut steel and brass strip. So far as the Bethlehem man could see, the blades seemed to be working fine. He looked at the customer and this time he detected a twinkle in his eye.

Leisure for Tool Grinder

"See that fellow over there?" And the customer pointed to a workman who was reading the morning paper. "That's our tool grinder, and he's a good one, too. He used to spend most of his time grinding blades. But those blades we made out of Lehigh H just seem to last forever. And every morning I have to rack my brains to find something else for him to do!"

The boss had a good laugh. Then he gave the salesman an order for more Lehigh H tool steel. He could afford to have his tool grinder idle much of the time. His shearing costs had been sliced in half.

High-carbon, high-chromium Lehigh H is just what the experienced toolmaker needs wherever maximum wear and minimum distortion are important. It's air-hardening, safe for intricate dies, thin sections, sharp corners. And it's deep-hardening, with high compressive strength for heavy-duty tools and dies.

Ten Times More Necktie Clasps with Hobbed Molds of Duramold A

Here's another enthusiastic report on Duramold A, our 5 per cent chromium, air-hardening hobbing steel. Hobbed for zinc die castings, this special-purpose steel has upped the life of molds by at least 1000 pct, according to Peerless Engineering Co., Inc., South Gate, Calif. In the casting of novelty necktie clasps, the die sets of Duramold A were examined at a time when previous molds had to be discarded. The Duramold A cavities showed no evidence of checking or sinking; and the surface finish appeared to have actually improved with use.

M. T. Derby, chief tool engineer for Peerless, sums it up:

"We like Duramold A because it's easy to hob. In making multiple cavities we get good detail and accuracy with fewer machine-hours. For most of our work we need a steel that gives us a high polish in the cavities with a high hardness that will stand up under zinc-injection molding at high pressures and temperatures. We've found Duramold A to have good core strength, it doesn't sink readily, and we can expect to get long runs with very little maintenance."

Whether used for die-casting or plastic-molding Duramold A is a real improvement over hard-to-hob steels. Its 5 pct chromium content provides plenty of wear-resistance and core strength . . . and its air-hardening properties hold distortion to a minimum during heat-treatment.

Duramold A is hobbed in one push in a 300-ton press by the master hob shown at top. Eight necktie clasps are cast at one time, the molten zinc being injected at 800 F and 2000 psi, mold temperatures reach about 300 F.

Its typical analysis:

C	Mn	Si	Cr	Mo
0.07 max	0.40	0.20	4.50	0.45

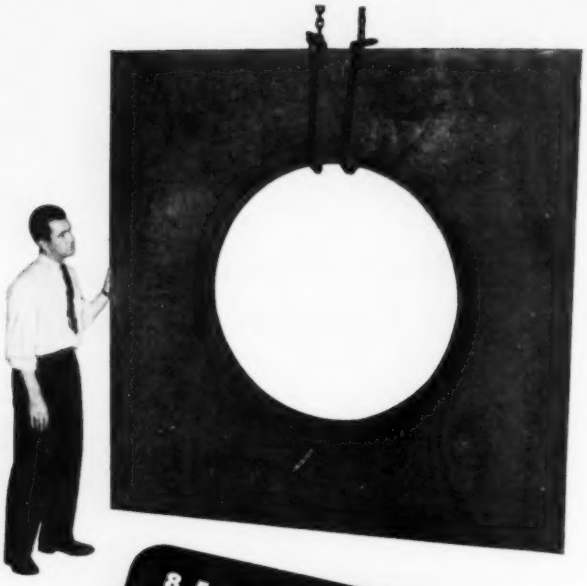
Booklet 271 will help you select the right tool steel — for hobbed molds, machine-cut molds, or master hobs. Address your request to our Publications Department, Room 1041, Bethlehem, Pa.

Our Tool Steel Engineer Says:

Poor tool design can cause cracking in heat-treatment

Proper attention paid to tool design can often prevent the cracking of tools during heat-treatment. Too often the heat-treater is asked to harden tools which cannot be quenched properly. One frequent design fault is a tool having a heavy section adjacent to a light section. Unnecessarily sharp corners is another design fault that can cause cracking. Provide fillets wherever sharp corners are not essential.

Bethlehem ULTRASONIC TESTED **Tool Steel**



FILLING A CRITICAL NEED

Stainless Type: 304 ELC
Plate Size: 4¼" x 96" x 96"
Hole Diameter: 52"
Outer Edges: Abrasive Cut
Hole: Powder Cut

SAVING VALUABLE TIME AND MATERIAL

Even well equipped shops are usually not set up to cut such large stainless plates to pattern easily, and this customer, like so many others, took advantage of our specialized cutting techniques and equipment. When this plate arrived in their plant pattern cut, fabrication could proceed at a rapid pace—with no loss of much needed material and with significant savings in time and labor.

Stainless steel is our only business . . . and we know it.

G.O. CARLSON, INC.

Stainless Steels Exclusively
300 Marshalton Road, Thorndale, Pa.
PLATES • FORGINGS • BILLETS • BARS • SHEETS (No. 1 Finish)
District Sales Offices and Warehouse Distributors in Principal Cities

Metal at Low Temperature

(Continued from p. 80)

temperature is very sharp and occurs at about −15° C. (5° F.). Additions of carbon within the range of 0.01 to 0.03% sharply raise the transition temperature, thus indicating that carbon in iron exerts an embrittling effect.

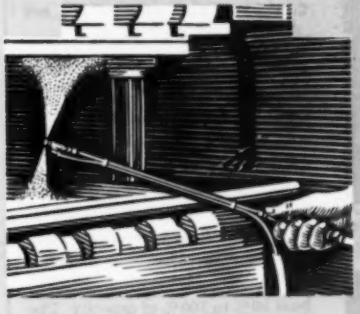
However, additions of manganese to the pure iron and the iron containing a little carbon lower the transition temperature, which suggests that manganese has a profound effect on the condition of the carbon in the iron — and this, he considers, is at least as important as the effect of the dissolved manganese atoms. Oxygen in excess of 0.003% causes a marked increase in the transition temperature, and the appearance of intercrystalline fracture in such materials indicates a weakening of the cohesion at the boundaries. Such embrittlement may be closely associated with intercrystalline films. It is quite conceivable that this filming has an important bearing on the lowering of the transition temperature by the expedient of grain refinement.

Mr. Allen stated that such grain boundary films could be less concentrated and of smaller dimensions in the finer grain materials, thereby lessening their effect on the cohesive strength between the grains. Iron containing oxygen thus provides a clear example of a material containing a serious weakness, which is not detected by a tensile test at room temperature and is detected by a notch-bar test or a test at low temperature. With respect to alloying additions, it appears that the elements of small solubility generally appear to be the most effective in producing brittle fractures, thereby raising the transition temperatures. The solution effect of heat treatment generally results in a transition temperature which is lower than that obtainable in the untreated material.

D. A. Shinn, of Wright-Patterson Air Force Base, presented a paper prepared in collaboration with J. B. Johnson, also of Wright-Patterson, on "Application of Metals in Aircraft at Low Temperatures". He stated that the lowest temperature which modern aircraft will encounter in stratosphere flight is about −90° C. (−130° F.). However, shock loading at low altitudes is not critical, unless the member is subjected

(Continued on p. 110)

NO SMOKE... NO FUMES
in Hot Forging with...
"dag" Colloidal Graphite



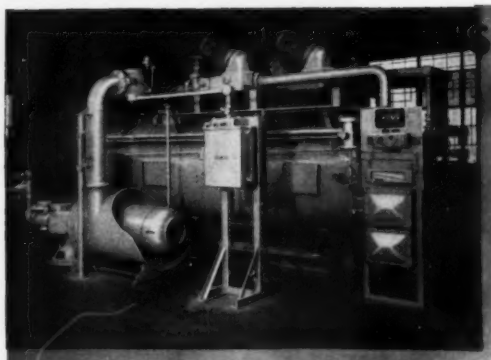
"Dag" colloidal graphite dispersed in water eliminates smoke and fumes in hot forging operations . . . greatly improves working conditions. The lubricating properties of colloidal graphite are superior, too, giving increased production . . . reduced die wear . . . better finish . . . and usually a saving in steel stock.

The uses of **"dag"** colloidal graphite for hot forging operations are fully explained in a specially prepared article entitled "Forging Die Lubrication". Copies are available without obligation. Write today to Acheson Colloids Corporation, Port Huron, Michigan, for Bulletin #750-10G.

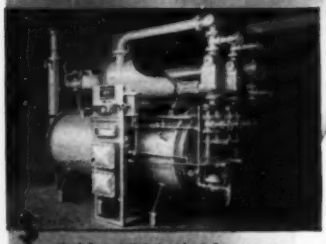
dag
DISPERSIONS

Acheson Colloids Corporation

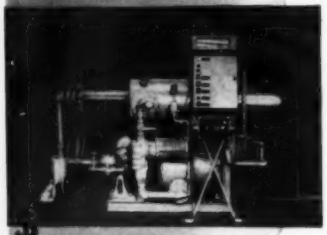
Port Huron, Mich.
...also Acheson Colloids Limited, London, England



Why Pay Premium Prices For Inerts?



Model 6 MINE is ideal for agitating, bubbling and blanketing in synthetic resin plants . . . delivers 6000 cfh.



Model 1 MINE offers all the features of larger equipment . . . delivers 1000 cfh . . . is fully automatic.

KEMP Inert Gas Producers Can Save You up to 90% on Inert Gas Costs

Whether you now use bottled inerts or produce them with old-fashioned equipment, switch to a Kemp Inert Gas Generator and save 83% to 90% on your inert gas costs. Kemp Inert Gas Producers and Kemp Nitrogen Producers are available in standard models with capacities ranging from 500 to 200,000 cfh for fully automatic operation.

ABSOLUTELY DEPENDABLE

No matter what the demand, Kemp Inert Gas Generators give you the same analysis Inert Gas from 20% to 100% of capacity. The Kemp Industrial Carburetor, part of each installation, burns ordinary gas just as it comes from the mains. Assures complete combustion without "tinkering." Produces a clean, chemically inert gas to meet your most exacting requirements.

SEND FOR DATA

Whatever your requirements, always specify Kemp. *To find out how you can benefit:* Tell us your atmosphere gas problem, and we'll show you how Kemp can solve it and save you money!

KEMP OF BALTIMORE

INERT GAS GENERATORS

Write for Bulletin I-10 for technical information.
C. M. KEMP MFG. COMPANY,
405 E. Oliver St., Baltimore 2, Md.

Metal at Low Temperature

(Continued from p. 108)

to ballistic or explosive impacts. The laboratory data on standard and notched specimens at low temperatures indicate that the allowable design values determined at room temperatures for standard aircraft metals are safe for low-temperature operations. Most low-temperature failures of aircraft materials are caused by unequal contraction of dissimilar materials which produces galling or binding with resultant overstress and distortion failures. Because of the scarcity of alloying elements, the use of valuable alloy to reduce the transition temperature should await a thorough diagnosis of the effect of lowered ductility at subzero temperatures on the serviceability of the part.

V. N. Krivobok, of International Nickel Co., Inc., in his paper, "The Properties of Austenitic Stainless Steel at Low Temperatures", presented data showing the effect of composition, heat treatment and cold working. The beneficial influence of extra-low-carbon content in the austenitic stainless steels is particularly noteworthy. Data on modulus of elasticity, fatigue, impact, tensile impact and other properties were summarized and appraised. Although the hardened high-chromium stainless steel has higher strength characteristics than the 18-8 type at room temperature, the low-temperature properties of the latter are considerably better, particularly as regards toughness. It is noteworthy that the ultimate tensile strength of 18-8 is greater for the notched specimen than for the unnotched type. Data were presented showing that while the impact values at room temperature for 18-8 are lower in the notched than in the unnotched bars, the ductility in the notched bars was at least as high. At subzero temperatures, the notched specimens showed the greater impact and ductility values.

Walter Crafts and C. M. Offenhauer, from Union Carbide and Carbon Research Laboratories, presented data on low-temperature service of a special low-alloy chromium-copper-nickel steel containing carbon 0.12% max., manganese 0.65 to 0.85%, silicon 0.15 to 0.25%, copper 0.40 to 0.60%, nickel 0.50 to 0.75% and chromium 0.65 to 0.85%. Such steel has rather good atmospheric corrosion resistance, welds readily and has successfully served

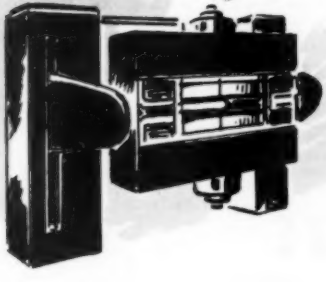
(Continued on p. 114)

Do You know

that new technics using the .00005 sq. in. focal spot of the Allis-Chalmers 22 MEV Betatron bring to the radiography of light metals a degree of detail sharpness unapproachable with conventional x-ray methods? And that you can easily get 1% sensitivity in sections from 1 inch to 12 inches thick?

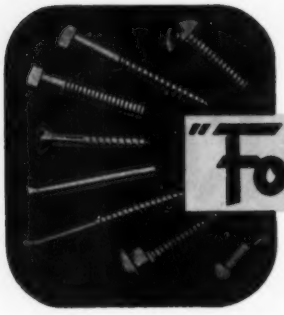
If you require high-precision inspection of light metals on a mass-production basis it will pay you to investigate this and other benefits of radiography with the 22 MEV Betatron.

Write Picker X-ray Corporation
300 Fourth Avenue, New York 10



ALLIS-CHALMERS
22 MILLION VOLT
Betatron
MAGNETIC INDUCTION ELECTRON ACCELERATOR

Picker X-ray



"Formbrite"

GOOD NEWS for those who use Cold Heading Wire

THIS MAY BE THE FIRST TIME you've heard of "Formbrite." But to those who fabricated the millions of pounds we've produced in the past year, Formbrite represents a long forward stride in the metallurgical development of Cold Heading Wire.

The name "Formbrite" designates a special process of rolling or drawing, plus a special heat treatment which imparts a superfine grain to copper-base metal. At present Formbrite is produced only in certain brass alloys.

The advantages? Formbrite Cold Heading Wire is bright, clean, strong and "springy"—yet possesses a degree of workable ductility unlike any wire you've seen of equal strength and hardness. That's what makes it so desirable for rivets, wood screws, machine screws and a host of other cold upset products.

Where parts are to be polished or plated, fine-grained Formbrite offers definite money-saving advantages on buffing, polishing and tumbling operations. Moreover, Formbrite Cold Heading Wire is supplied in *one* temper, resulting in simplified stocks and inventory.

Formbrite is produced in the form of sheet, strip, rod, wire and seamless tube—at no increase in price. For deep-drawn polished or plated parts, it's been nothing short of sensational. Want to compare Formbrite with ordinary drawing brass in your own polishing room? Then write for a kit of two sample cups—plus additional information about Formbrite. Address The American Brass Company, General Offices, Waterbury 20, Connecticut. B1100

Formbrite is a trade mark of The American Brass Company designating copper-base alloys of exceptionally fine grain, combining unusual polishing characteristics with strength and hardness, plus excellent ductility.

ANACONDA

the name to remember in

COPPER·BRASS·BRONZE

Reynolds
ALUMINUM REPORTER
A SERVICE TO INDUSTRY ON ALUMINUM USES AND DEVELOPMENTS

LOUISVILLE 1, KY. NUMBER 5

REYNOLDS OPERATING MICHIGAN AIR FORCE PLANT

Aluminum Right for Hardware Fittings

Aluminum offers many qualities that add both appearance and durability to hardware fittings. It also is more economical than any other non-ferrous metal and is more desirable from several standpoints.

Aluminum hardware has a lasting, bright natural finish that requires no protective coating. And if special decorative effects are required, aluminum takes an extremely wide variety of finishes. In addition, aluminum offers strength with less weight for handling and shipping.

The hinge illustrated above is a good example of how the extrusion process can cut costs and simplify production of aluminum hardware. The undrilled piece is a section of an aluminum extrusion which is cut to specified hinge lengths. The tubular edge is then milled for mating hinge leaves. When screw holes are drilled and counter-sunk, hinges are ready for assembly with an aluminum pin. Decorative knobs made from aluminum screw machine stock are optional.

The extrusion process is also ideal for combining several elements into a single unit to eliminate excessive and costly assembly operations. A new 16 mm., sound-color movie, "The Shape of Things to Come" describes a variety of actual applications and the extrusion manufacturing process. Running time is 30 minutes. This movie is available without charge for individual showings, when requested on business letterhead. Write to Reynolds Metals Company, Motion Picture Dept., 2576 South Third Street, Louisville 1, Kentucky.

World War II Aluminum Extrusion Center now U.S.A.F. Manufacturing Methods Development Plant

The Reynolds Metals Company has taken over the management of the U.S. Air Force's Manufacturing Methods Pilot Plant at Adrian, Michigan.

Reynolds will operate the 20-million dollar government-owned facility without fee or profit to develop new forging and extrusion techniques and to prove theoretical designs for products in *all* metals.

The plant is available to any industry or government agency interested in development work on processes of either military or non-military interest.

A number of large manufacturing firms have already contracted for the use of Adrian plant and its development facilities.

The Curtiss-Wright Aircraft Company, in conjunction with the Air Force, has developed a new method for producing a hollow steel propeller by an improved extrusion technique. A 200 pound, 10-foot propeller blade tube is produced from a white-hot, 460 pound chrome-nickel molybdenum steel billet in minutes. This process, which is accomplished in three major stages, eliminated time-consuming operations of welding together, brazing and forming of two specially-processed flat plates which weigh 750 pounds before machining to produce the same size blade. At the same time this new process improves blade quality and strength-weight ratio.

Equipment in the plant consists of 16 hydraulic extrusion presses, largest of which is of 5,500 ton capacity. Others are of the 3,850-ton, 2,750-ton, and 1,650-ton capacity sizes. In addition, four German forging presses from the I. G. Farben Industries, with capacities, of 660—2,200—7,700 and 16,500 tons are now installed.

The factory building itself contains 700,000 square feet and is situated on a 73 acre site. No actual production will take place in the plant under the contract with Reynolds, except in the case of national emergency.

With the facilities at this new plant, Reynolds will promote constant research and development of new production methods.

For more information, write for copy of the new 24-page brochure detailing Adrian facilities and how they can serve you. Address your letter to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Ky.

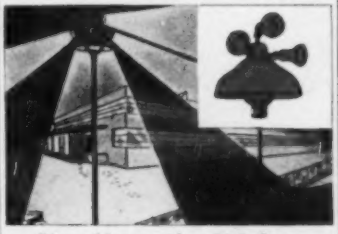
Die Cast Lighting Fixtures for Outdoor Use Afford Greater Defense Plant Security

Plants throughout the country, requiring dependable outdoor lighting systems for military security reasons, are turning to the use of die cast aluminum lighting fixtures.

The light weight, rust-resistant qualities of aluminum provide safe and economical operation of lighting systems that must function at peak efficiency despite exposure to severe climatic conditions.

Cast aluminum cluster lighting fixtures of this type are made by the Killark Electric Mfg. Company of St. Louis, Missouri. They have been proven in use for flood or spot systems on farms and factories, billboards and parking lots.

These fixtures make daylight out of darkness, and help put the permanence needed in outdoor lighting systems. Killark also manufactures a fully complementing line of aluminum light shields, wiring troughs, acorn fittings, extensions and adaptors. All are made



Directed beams with multiple fixture

of aluminum, assuring years of dependable performance.

Check the many advantages of die cast aluminum—minimum machining, fast production, durability, low cost—and see if it can help in your production problems. Call on the complete staff of Reynolds technicians for help in your designing. Look for the Reynolds office listed under "Aluminum" in your classified telephone directory. Or, write the Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

MORE INTERESTING NEWS ABOUT ALUMINUM ON NEXT PAGE

Printed in U. S. A.

Fabricating Service Speeds Production, Saves Scrap

Carting 5-inch rockets to Corsair, Skyraider for loading

Aluminum Rocket-fin Example of Service to Industry

Aluminum rocket fins guiding 5-inch rockets now being used by the air forces in Korea are among the many production items Reynolds Fabricating Service is engaged in producing for the Armed Forces. In the photo above, crewmen of the Navy and Marine Corps are shown preparing to load these effective missiles aboard war-planes for use against the enemy.

Although Reynolds is doing the basic mass-fabricating on the components, considerable amount of the assembly (including spot welding, seam welding, servicing and packaging) is being shared on a sub-contract basis with other aluminum fabricators under the Reynolds "Share-the-Work" plan.

This is only one example of the valuable service made available to manufacturers through the use of the Parts Fabricating Service. Formed or partially-formed parts are delivered to the manufacturer ready for finishing and assembly, resulting in scrap savings averaging 30% and valuable time gains.

Blanked parts eliminate costly tie-up of shipping and stockroom space . . . save in scrap handling and storage, make scarce material available for instant remelting.

The manufacturer gets exact number of parts needed and is assured of maximum efficiency and a steady flow of inspected parts in any quantities or stage of completion desired.

Reynolds Aluminum Parts Fabricating Service is the *complete* service with equipment for shearing, forming, tube bending, roll forming, roll shaping, riveting, welding and finishing.

Reynolds is set up to work in co-operation with both large and small manufacturers. This program is directed toward combining the resources of all of the nation's businesses to supply the needed production for today's large volume of defense orders.

For complete information on how the Reynolds Parts Fabricating Service can help you, write for the free booklet, "Pounds of Parts...instead of Pounds of Metal". And for assistance on *special* aluminum fabricating problems, call the Reynolds office listed under "Aluminum" in your classified telephone directory. Or, write Reynolds Metals Company, 2065 So. Ninth St., Louisville 1, Kentucky.

Aluminum Chicken-Blinders Cut California Cannibalism

Our West Coast office has forwarded to us one of the most unusual aluminum items we have ever run across. In father's day, horse-blinders were common equipment, but now we have, believe it or not, *chicken-blinders!*

Poultry growers have long known that chickens are cannibalistic. The sight of fresh blood will incite large flocks of fowl to the extent that they turn and tear their kind to pieces. On large ranches, thousands of chickens have been killed at one time.

Chicken-blinders, stamped from sheet aluminum and fastened to the beak with a cotter pin, prevent the bird from seeing directly ahead and eliminates the urge to battle.

Although there are blinders made of other material on the market, the aluminum type has proven most satisfactory in service. The light weight combined with its non-corrosive qualities make it ideal for use under the type of conditions found in poultry yards.

Aluminum Foil Meets Military Packaging Specifications

Barrier Material, Grade A and Acetate Bonded Wraps Ready for Many Defense Purposes

Reynolds Aluminum Foil has moved from the pantry shelf to the shipping line in defense production plants throughout the country. The Reynolds Metals Company has turned the production of the valuable and versatile aluminum sheeting into packaging material that will meet the government's strictest military packaging requirements. The company has prepared a booklet, available upon request, containing samples and complete specifications for these requirements.

Aluminum Foil by itself and in combination with other materials answers thousands of packaging problems. From powdered milk to aircraft engines, wrenches to rifles, the moisture-proof, corrosion-resistant qualities of aluminum provide the ideal wrap for protective shipment.

Acetate-Bonded Aluminum for Soluble Coffee, Powdered Milk, Sugar, Tea, Salt, Concentrates, Assault Rations, etc. Printed, pliable material for high-speed packaging. Takes firm, impenetrable heat seal...moisture-vapor proof, holds flavor, protects against contamination and light rays. Widths from 2" to 25"—takes reverse printing.

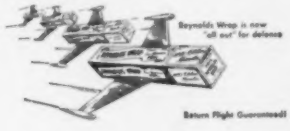
Barrier Material for Accessory Packaging. Very flexible foil-on-kraft with waterproof laminant and clear Vinyl Heat Seal Coating. For small packages — medical supplies, cigarettes, bandages, ration material and other quartermaster applications. Standard widths 24" and 36" for own printing and automatic packaging. Or write for data on preformed printed packages.

Barrier Material for Bags, Interior Packaging is a heavier version of above for larger bags, rougher handling. Also meets basic material specifications for a Grade A non-corrosive wrapping material. Tough and tear-resistant, supplied in same widths and style as above.

Barrier Material for Method II Packaging. Triple lamination of foil, cloth and heat-sealing plastic sheet. Designed for highest degree of moisture-vapor and physical protection—the Method II (carton-barrier-carton) application with desiccant. Standard 36" width.

Aluminum Foil Grade A Wrap. For odd shapes, eliminates taping or tying, saves time in packing. Under certain moist atmospheric conditions, protects against galvanic and contact corrosion of metal parts. In .001", .0015", .002" and .003" gauges.

Reynolds Technical Service is at your disposal with extensive research facilities for development of new materials and packages. For free copy of booklet "Barrier Material for Military Packaging," contact your Reynolds Sales Office or write on business letterhead to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

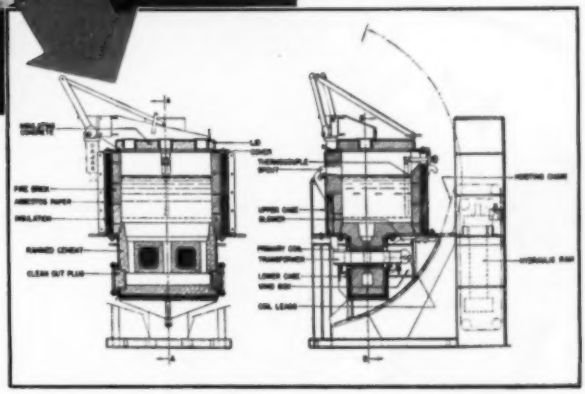


AJAX TAMA-WYATT INDUCTION FURNACES

Cut Foundry Melting Cost

Partial view of National Pressure Cooker Co.'s melting room showing Ajax Induction Furnaces.

Accurate records at the National Pressure Cooker Co., Eau Claire, Wisc., show that over a two-year period the Ajax Induction Furnace was capable of reducing melting costs by as much as 40%.



Cross section drawings of 166 kW. twin-coil Ajax Induction Furnace with hydraulic tilting device, same as shown in photograph above.

Due to the nature of their use, pressure cooker castings must maintain exceptionally high standards of casting quality. Not only does the induction furnace effect a saving in melting cost but, in addition, working conditions are greatly improved.

Note from the diagram above that the operation of the Ajax furnace is based on the induction principle, whereby energy is transmitted to the molten charge without actual contact, through the refractory walls. Only the metal is heated, and therefore there are no resistors or other parts having a higher temperature than is absolutely necessary for properly melting the charge. A gentle movement of the bath insures uniform temperature and homogeneous mixing of the ingredients. Linings are made of inert refractories which do not contaminate the melt. Temperature control is entirely automatic.

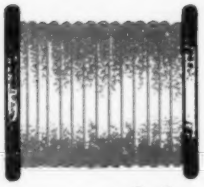
Write for Further Facts and Information

AJAX TAMA-WYATT

AJAX ENGINEERING CORPORATION, TRENTON 7, N. J.

INDUCTION MELTING FURNACE

AJAX ELECTRO METALLURGICAL CORP., and Associated Companies
AJAX ELECTROTHERMIC CORP., Ajax Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC., The Ajax Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax Wyatt Induction Furnaces for Melting



Bright Annealing of Copper

HOLCROFT'S
HIGH-PRODUCTION FURNACE
MINIMIZES OXIDATION

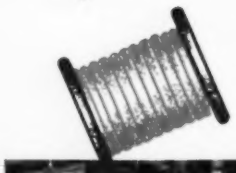
Typical of Holcroft trail-blazing in furnace engineering, this high-production gas-atmosphere unit handles bright annealing of wire, strip and bar stock of copper and non-ferrous copper alloys. Note these special features:

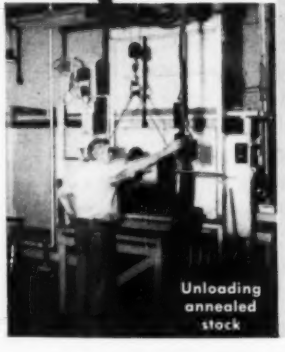
- Except for loading and unloading, operation is fully automatic. Coiled stock is loaded on trays as shown. Bar stock can be annealed simultaneously in bank of six tubes at top of furnace. Production is 4000 lbs. per hour.

- Special Holcroft gas generator under automatic control provides inert protective atmosphere surrounding work in process. Gas is free of sulfur and oxygen, with negligible hydrogen and CO content. Gas-tight furnace and vestibules plus automatic flushing further assure uncontaminated work.

- Heating is by Holcroft electric elements, quickly replaceable without shutting down furnace. Gas-fired radiant tubes can be used where more economical. Heating zone is held at any desired temperature from 500° to 1150° F. Annealing zone is water-cooled.

- These, plus other Holcroft features, assure maximum economy and quality of work, as proven by four years of continuous operation at Canada Wire and Cable Company. These same production advantages are found in Holcroft furnaces for every heat treat requirement; for each Holcroft furnace is individually designed for its specific application and is backed by complete metallurgical and engineering service.





We cordially invite your inquiries.

BLAZING THE HEAT TREAT TRAIL

SINCE 1916 Holcroft AND COMPANY

BUILT BY HOLCROFT & COMPANY DETROIT MICH

PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

6545 EPWORTH BLVD. DETROIT 10, MICHIGAN

CHICAGO 9 C. H. Martin, A. A. Engelhardt 4200 South Western Blvd.
CLEVELAND 15 Wallace F. Schott 1900 Euclid Ave.
HOUSTON 1 R. E. McArdle 5724 Navigation Blvd.
CANADA Walker Metal Products, Ltd. Windsor, Ontario
EUROPE S. O. F. I. M. Paris 8, France

Metal at Low Temperature

(Continued from p. 110)

for over 15 years in several installations at temperatures as low as −80° C. (−112° F.). Recent tests have indicated that certain heats of these steels retain good toughness at −100° C. (−148° F.). These studies indicated that the limiting factor was the appearance of the "pseudo-martensitic" microstructural constituent, controlled mainly by the amount and balance of carbide-forming elements and secondarily by the austenite-forming elements. Aluminum tended to inhibit the formation of this nonpearlitic constituent and also was a significant factor in lowering the transition temperature. It was concluded that consistent notch-bar impact strength can be realized in the alloy at −100° C. if the residual aluminum is high enough to insure persistently fine grain size, and further lowering of the transition was indicated if the residual aluminum content approached the 0.2% level.

SIZE AND DESIGN FACTORS IN FRACTURE

C. W. MacGregor and N. Grossman, of Massachusetts Institute of Technology, presented a paper which dealt primarily with dimensional and design effects of test specimens on their fracture characteristics. Flat circular disks of 0.95% carbon steel, simply supported around the circumference and loaded by a concentrated force at the center, were tested at constant deflection rates and at various constant temperatures. Comparisons were made of the transition temperatures for brittle fracture at the same effective strain rates rather than at equal deflection rates in order to maintain dynamic similarity. Size effect in the ratio ranges of 6 to 1 for the material tested had no significant effect on the brittle transition temperature. Rectangular plates ¼ in. thick of the same steel, simply supported on two sides only, were centrally loaded to study the influence of biaxiality of stresses on the brittle transition temperature. Ratios of the supported lengths to the unsupported lengths varied from 0.5 to 2.667, which produced a variation of the biaxiality of stresses from 0.483 to 0.855. Together with the circular disks previously described, these limits would be 0.483 to 1.0.

(Continued on p. 116)

Geared

to efficiency in your furnace line

ONE CONTRACT ONE RESPONSIBILITY

Wherever HEAT is used in INDUSTRY

It's LOFTUS all along the Line

You will realize dollar savings with a Loftus "coverall" contract. Better design . . . New methods . . . Dependable components give you greater versatility, uninterrupted production . . . and finer products.

You are assured of maximum dependability and efficiency when your equipment is built by Loftus Industrial Heating specialists.

It will pay you to consult the Loftus organization. Loftus is one of the largest in the country, staffed with men individually specializing in all of the various phases of industrial heating.

Inquiries Invited

610 SMITHFIELD ST. **LOFTUS ENGINEERING** *Corporation* PITTSBURGH, PA.

Designers and Builders of Industrial Furnaces

whether your product must be finished for corrosion resistance or paint adherence, or with eye-appealing brightness or in a variety of attractive colors, ... there's an IRIDITE® to do the job!

Zinc, cadmium, aluminum, copper, brass or bronze, in their usual commercial forms, can be finished with Iridite for a fraction of a cent per square foot . . . and without costly special equipment or personnel training. In addition, our ARP plating chemicals . . . brighteners, addition agents, etc. . . . can increase the efficiency of your plating solutions prior to Iridite treatment.

Let the experience of our field engineers and laboratory specialists be your guide to the solution of your specific finishing problem.

We'll welcome the opportunity to work with you in the development of new materials as new finishing problems arise from your manufacturing plans. *Write for information, or send samples of your product for free test processing.*

Iridite is approved under government specifications.

ALLIED RESEARCH PRODUCTS
INCORPORATED
4004-06 E. MONUMENT STREET • BALTIMORE 5, MD.

Metal at Low Temperature

(Continued from p. 114)

The brittle transition temperature, the fracture stress, and constraint effect were found to increase with increase in the biaxiality ratio.

The closing paper, "Tensile Properties of Copper, Nickel and Some Copper-Nickel Alloys at Low Temperatures", by G. W. Geil and N. L. Carwile, of the National Bureau of Standards, discussed tension data obtained at temperatures ranging from +100 to −196° C. for high-purity copper and nickel and for the 70-30 and 30-70 alloys of these metals in the annealed conditions. The "rim effect" (contraction of the specimens at the base of the neck during actual fracture) was considerable and tended to decrease as the temperatures were lowered. Because of this rim effect, accurate values of the true stress (σ) and strain (δ) at fracture can be determined only from measurements made at the initiation of fracture. The true stress-strain tension data did not conform to the commonly accepted parabolic relationship $\sigma = k\delta^m$, but the strength indexes, as represented by the initial strength, nominal ultimate stress, true stress at maximum load and true stress at initial fracture, increased continuously with decrease in temperature within the range tested. The uniform strain (true strain at maximum load) generally increased with decrease in test temperature; however, no general trend was indicated in the slight variation of total strain (true strain at initial fracture) with temperature. The rates of work hardening at specific true strain, in general, increased continuously with decreased temperatures. For small true strains, the increase in the rates of work hardening of the cupro-nickel and the 70% nickel, 30% copper alloy with decrease in temperature was less than that of either the copper or nickel, but for larger true strains (greater than 0.2), the work hardening rates were greater for the alloys.

An interesting moving picture, narrated by M. J. Disckind, of Towne Scientific School, University of Pennsylvania, recorded the progress of the transformation of white (β) tin to the gray (α) form at −20° C. (−4° F.). Cast polycrystal and single crystal specimens of high-purity tin were the actors. To facilitate the transformation, a seed of gray tin was impressed in the surface of

(Continued on p. 118)

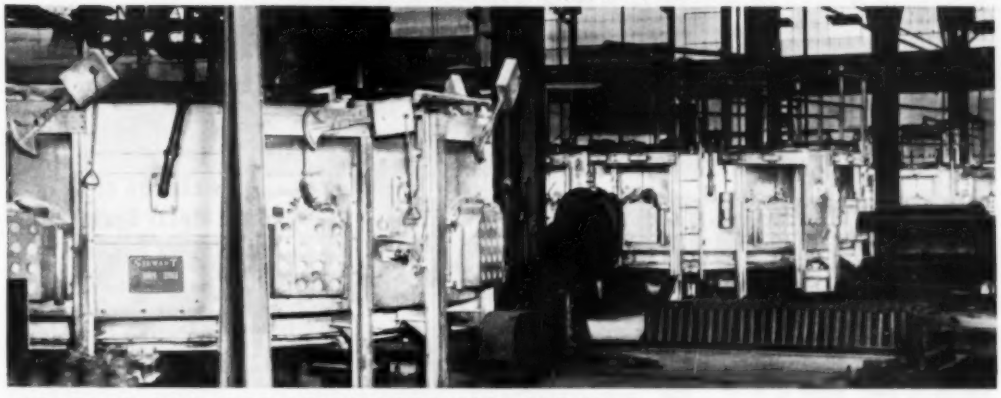
No. 107 of a Series of Typical Installations

Sunbeam STEWART

THE BEST INDUSTRIAL FURNACES MADE

HOW SUNBEAM STEWART FURNACES MEET THE DEMANDS ON THE PRODUCTION FRONT

DEFENSE REQUIREMENTS CAN BE MET QUICKLY WITH PROVEN SUNBEAM STEWART HEAT TREATING EQUIPMENT

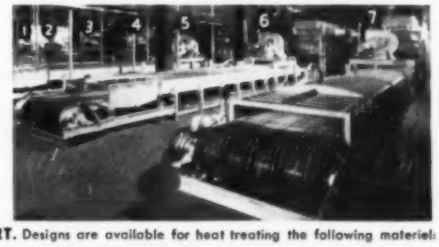


HEATING PROJECTILE BILLETS FOR FORGING—Three of nine Sunbeam Stewart Rotary Hearth Furnaces that met the demand for fast, uniform production during World War II are shown above. This installation is typical of the Sunbeam Stewart units designed to meet the defense requirements of the present emergency.

Sunbeam Stewart's circular-tunnel rotary hearth design, sand-sealed and friction-driven at three points has been proven by years of heavy-duty, 24-hour-a-day operation. Multizone control plus the sand-seal feature guarantees the thorough, even heat good forging practice requires with scale problem reduced to a minimum.

Sunbeam Stewart Engineers have developed both Rotary Hearth and Pusher-type Forging Furnaces. Both designs feature simplicity of operation and the ability to heat quickly with even heat distribution and close temperature control.

SHELL LINE HEAT TREATING. Seven of these complete Sunbeam Stewart Shell Lines shown at right were used in one leading plant during World War II. From the time shells were loaded in the Hardening furnace until they were taken from the cooling chamber conveyor belt, all processes were completely automatic—reducing man power required and insuring proper temperatures and cycle. When the shells emerged, they were ready for shot blasting and final machining operations. Sunbeam Stewart designed and installed many similar lines.



IF YOU ARE CONSIDERING DEFENSE WORK CALL SUNBEAM STEWART. Designs are available for heat treating the following materiel:

SHELLS: 57MM; 75MM; 90MM; 105MM; 120MM; 155MM; 3", 5", 6", 8" Navy Shells (Harden, Quench and Draw).

FORGINGS: Rotary Hearth and Pusher-type Forging Furnaces.

ARMOR PIERCING SHOT (Harden, Quench and Draw).

CARTRIDGE CASES (Anneal, Stress Relieve).

MACHINE GUN CLIPS (Harden, Quench and Draw).

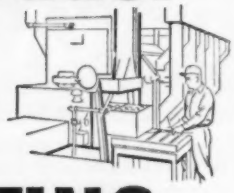
Sunbeam STEWART **INDUSTRIAL FURNACE DIVISION of Sunbeam CORPORATION**

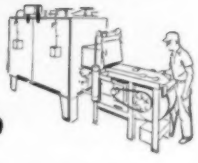
(Formerly CHICAGO FLEXIBLE SHAFT CO.)

Main Office: Dept. 05, **4433 W. Ogden Ave., Chicago 23**—*New York Office:* **322 W. 48th St., New York 19**—*Detroit Office:* **3049 E. Grand Blvd., Detroit**
Canada Factory: **321 Weston Rd., So., Toronto 9**

A letter, wire or 'phone call will promptly bring you information and details on SUNBEAM STEWART furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM STEWART engineer will be glad to call and discuss your heat treating problems with you.

if your product calls for HEAT-TREATING... it calls for a WESTINGHOUSE FURNACE... gas or electric





There's a Westinghouse Furnace to provide the exact answer for every heat-treating application, gas or electric:

- **standard types for established techniques and practices**
- **semi-standard types and auxiliaries**
- **special furnaces engineered to your specifications and production system**

Consult Westinghouse first! See your nearby Westinghouse representative, or write Westinghouse Electric Corporation, Industrial Heating Division, Meadville, Pennsylvania. J-10366

YOU CAN BE SURE.. IF IT'S Westinghouse HEAT-TREATING FURNACES

Metal at Low Temperature

(Continued from p. 116)

each specimen before it was cooled. In the polycrystal specimens, the transformation progressed as a solid geometric figure outward toward the edges of the specimen. The process was completed in about 12 hr. and was accompanied by an increase in volume and disintegration of the metal. In the single crystal (which first was cold worked before "seeding") the transformation proceeded at first as a series of dendritic-like darts and then the transformation continued from the center of the specimen, much like that in the polycrystal material.

According to present plans, the series of nine papers will be published as a single volume at some future date.

Relation of Base Metal Surfaces to Plating Success*

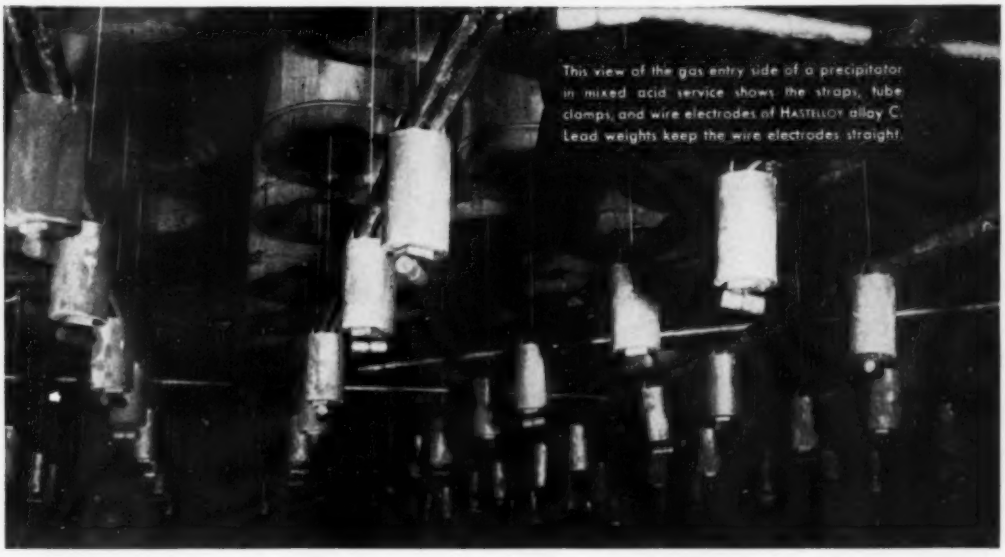
THE INFLUENCE of the base metal on the plate has long been recognized. In 1916, G. B. Hogaboom predicted that the crystal structure and grain size had an important influence on the plate. In 1921 he pointed to the fact that photographs of deposits showed some of the copper deposit crystals as continuations of the crystals in the copper basis metal. This was confirmed by W. Blum and H. S. Rawdon, A. K. Graham, and A. W. Hothersall.

These observations revealed that the structure of deposits is substantially dependent upon the condition of the basis metal, and that by controlling the basis metal surface, one may obtain a deposit with favorable structure, physical properties and adhesion. The last named is impaired principally by foreign material between the coating and basis metal, a weak layer of metal upon the surface plated or in the initial deposit, and stresses in the deposited metal.

It can be shown metallographically that the dominating influence in the success or failure of electro-

(Continued on p. 122)

*Abstract of "The Influence of Base Metal Surfaces on the Nature and Characteristics of Electrodeposited Metals", by A. T. Steer, a paper presented before the Australian Institute of Metals, Physical Metallurgy Division, 1949, as part of the Symposium on Electrodeposited Metals.



This view of the gas entry side of a precipitator in mixed acid service shows the straps, tube clamps, and wire electrodes of HASTELLOY alloy C. Lead weights keep the wire electrodes straight.

Precipitators Improved...

WITH NICKEL-ALLOY ELECTRODES

Electrostatic precipitators for removing corrosive liquids and solid particles from industrial process gases give better and longer service, without maintenance, when HASTELLOY alloy wire is used for electrodes. The alloy has excellent mechanical strength (130,000 psi) and is not attacked by the corrosive agents. This combination of properties makes it possible to use electrodes that are only 0.073 in. in diameter. The effective diameter of the lead-covered wire formerly used in most units was more than 0.500 inch. The smaller cross-section of the HASTELLOY alloy wire permits the use of higher voltages with a more uniform corona pattern.

HASTELLOY alloy C electrodes have been installed in mist precipitators where hydrochloric, sulphuric, sulphurous, and mixed acids were present. A recent check on an installation in an acid plant showed that the alloy C wires experienced no weight loss after a year's operation. Lead-covered steel wires, on the other hand, lasted an average of 11 months with electrode failure at least once a week.

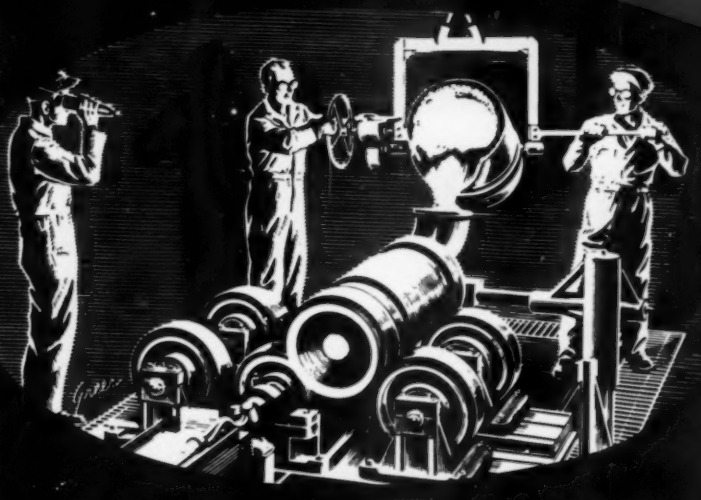
For information on wrought forms of HASTELLOY alloy, write for the booklet, "HAYNES Wrought Alloys Price List."

HAYNES TRADE-MARK *alloys*

"Haynes" and "Hastelloy" are trade-marks of Union Carbide and Carbon Corporation.

Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago — Cleveland — Detroit — Houston
Los Angeles — New York — San Francisco — Tulsa

family



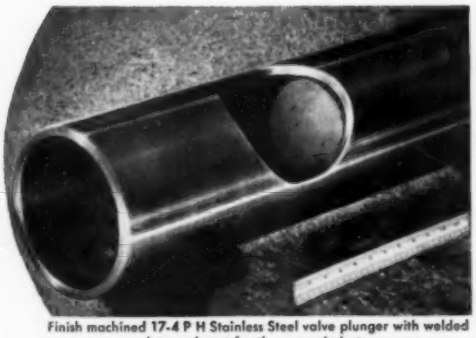
SPECIAL PRODUCTS DIVISION

U. S. PIPE AND FOUNDRY CO., BURLINGTON, NEW JERSEY

AMERICA'S LARGEST PRODUCER OF CENTRIFUGALLY CAST FERROUS METAL PRODUCTS IN TUBULAR FORM

portrait!

METAL MOLD CENTRIFUGAL CASTING SPELLS ECONOMY AND EFFICIENCY FOR WIDENING GROUP OF STAINLESS STEEL PRODUCTS



Finish machined 17-4 P H Stainless Steel valve plunger with welded plate and port for the paper industry.

Type 303 Stainless Steel stock from which rings and sleeves are fabricated for many industrial and defense applications.

Rough machined Type 316 Stainless Steel bowl casting for the food and processing industries.

Pictured here are a few of the many stainless steel products now included in the rapidly increasing family of products centrifugally cast for industry by our new metal mold process.

This method offers many specific advantages. For one, centrifugally cast stainless steel cylindrical sections, formed by pouring molten metal into rapidly spinning, refractory-coated permanent metal molds represent the ultimate in casting quality, imparting a fine, dense grain structure, unusually free from conventional casting defects.

You may find that your stainless steel product can be cast more advantageously by this versatile process. Our engineers will be glad to answer any of your questions.

SIZE RANGE AND COMPOSITION FLEXIBILITY

Outside Diameter — 4" to 30"

Wall Thickness — $\frac{3}{16}$" and up

Length — Up to 14' in the "as-cast" condition

Types of Stainless Cast — All standard AISI and ACI grades of ferritic and austenitic stainless, plus "Special" types

---

CHECK THESE ADVANTAGES FOR YOUR CYLINDRICALLY-SHAPED PRODUCTS:

- Reduced Processing Time and Increased Production.
- Minimum Scrap Loss.
- Design of parts to suit the specific job requirement by selecting the correct alloy — not the next best available alternate.
- Conservation of critical metals and alloys — especially on tubular parts now produced from solid sections.

Efficient Pickling with . . .

Rodine

PICKLING ACID INHIBITORS

SAVES ACID
SAVES STEEL
SAVES MONEY

Use RODINE in sulfuric and muriatic acid baths for improved pickling and increased production.

In straight line pickling of wire, rod and tubing, RODINE makes available more metal for drawing by protecting steel from acid attack. In batch pickling of sheet steel, RODINE improves the surface. In rapid, continuous strip pickling, RODINE not only saves acid and metal, but also prevents over-pickling during line shutdowns.

Now, more than ever, it is cheaper to pickle with RODINE than without it.

"RODINE" meets Government Specification No. U.S.N. 51-I-2.

STANDARD RUST PROOFING PRACTICE THE WORLD AROUND
CHEMICALS ACP PROCESSES

AMERICAN CHEMICAL PAINT COMPANY

AMBLER, PENNA.

Write for descriptive folder on RODINE Pickling Acid Inhibitors.

Base Metal Surfaces

(Continued from p. 118)

deposition rests almost entirely with the surface conditions existing on the base metal on which such deposition takes place.

METALLOGRAPHIC TECHNIQUE

The essential points to observe in preparing a specimen of electrodeposited metal are: *(a)* the metallographic polishing must be completed in 3 min., of which around 30 sec. are required to eliminate superficial scratches due to the final paper preparation; *(b)* the actual polishing must be effected by hand, as power polishers are far too drastic to deal with delicate surfaces of this nature; *(c)* the specimen on completion of polishing must be optically flat, free from scratches and, above all, absolutely clean. Observation of these conditions is imperative for specimens to be examined at magnifications ranging from 1500 to 3000 ×.

A further refinement can often be applied when resolving flow layers and minute zones of surface breakdown, particularly of the brasses, nickel-rich alloys, and similar materials. This consists of photographing the specimen at 2000 × and, by means of a very careful enlargement, increasing the scale of the image by five times, thus obtaining an equivalent to 10,000 ×. Such a magnification by enlargement does not increase resolution but does separate indeterminate structure. It is an invaluable aid in diagnosing faults associated with lack of adhesion and differentiating clearly between stress exfoliation and that accruing from faulty preparation prior to deposition.

The response of a metallic surface to an applied stress is a direct function of the properties of the crystals which constitute such a surface. The fact that a crystal responds to a stress by slipping, and that slip is not a continuous process — but appears to be that of yielding to a stress, and then opposing it until further slip ensues, due to an increase in the original stress itself — indicates that the process is not so much a mechanical movement of one block of atoms past another block, but rather that of a movement which increases the energy state of the atoms concerned. This energy gain will manifest itself as an increase in temperature with the

(Continued on p. 124)

"Command Performance..."

AT DETROIT

For Materials and Equipment at the 1951 METAL SHOW
week of OCT. 15-19, 1951

The National Metal Exposition determined *last* year what its audience of buyers wanted to see at the Metal Show *this* year—materials, equipment, processes, products.

More than that, a scientific survey of the Metal Show audience tells you who attends—from top management through production and on down the line—where they come from, and the type of businesses they represent.

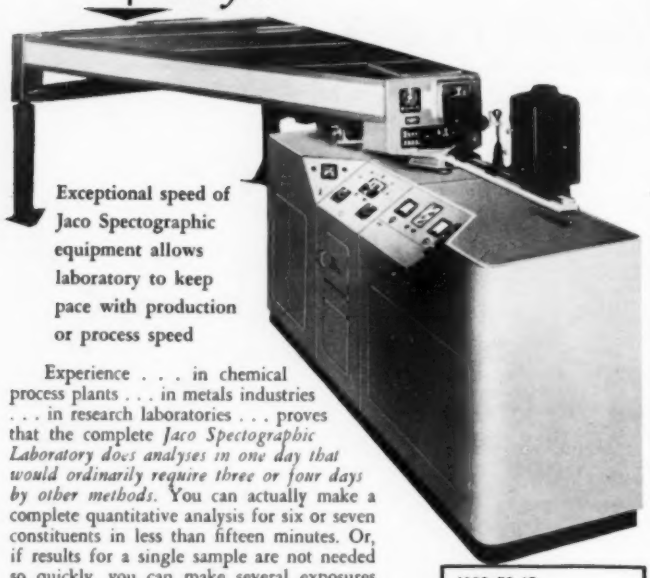
As an exhibitor in the Detroit Metal Show, you will come face to face with an audience representing the greatest industrial market center in America.

Write or phone today for details of good space locations still available.

12,420	BUYERS	Want to see Ferrous Metals
15,303	BUYERS	Want to see Furnaces
14,982	BUYERS	Want to see Shop Equipment
11,423	BUYERS	Want to see Materials Handling Equipment
14,627	BUYERS	Want to see Welding Equipment
9,146	BUYERS	Want to see Non Ferrous Metals
8,541	BUYERS	Want to see Castings
14,911	BUYERS	Want to see Testing and Inspection
12,811	BUYERS	Want to see Protective Coatings
10,640	BUYERS	Want to see Metal Cleaning & Finishing

NATIONAL METAL EXPOSITION
7301 Euclid Avenue Cleveland 3, Ohio

Now *300% to 400% (even 1000%) faster Research and Production Control analyses*



Exceptional speed of Jaco Spectographic equipment allows laboratory to keep pace with production or process speed

Experience . . . in chemical process plants . . . in metals industries . . . in research laboratories . . . proves that the complete *Jaco Spectographic Laboratory does analyses in one day that would ordinarily require three or four days by other methods.* You can actually make a complete quantitative analysis for six or seven constituents in less than fifteen minutes. Or, if results for a single sample are not needed so quickly, you can make several exposures on each photographic plate and cut analysis time per sample even more.

But there's more to the story than *speed* — Jaco Spectographic Equipment is as *precise* as it is fast. Overall accuracy of ±3% of amount present is possible, and in low percentage problems as little as 0.001% and even less of trace elements are easily determined quantitatively (0.0006% Boron in steel, for example).

These are only a few of the many advantages that are yours with Jaco Spectographic Equipment. Find out more by writing for *all* the details today.

JACO 70-15
Stigmatic Grating
SPECTOGRAPH and VARISOURCE EXCITATION UNIT

SPECTOGRAPH (left, above): The only stigmatic grating instrument commercially available! Fully automatic instrument for fast, precise analysis of ferrous alloys, minerals and for use in dozens of other spectochemical analytical problems. Electrical controls are simplified, and grouped for maximum flexibility and convenience. Toggle switch wavelength region shifting. Electromagnetic shutter controlled from source . . . 6" grating, blank (15,000 lines per inch) for high optical speed and superior resolution . . . plateholder accommodates two 4" x 10" plates for maximum single exposure spectral coverage.

New VARISOURCE EXCITATION UNIT (right, above): All-in-one excitation source — includes DC arc, high-voltage AC arc and high-voltage tandem air-gap spark with oscilloscope control. High reproducibility and precision.

JACO
projection comparator
MICROPHOTOMETER

Designed especially by Jaco for your most exacting requirements. Measures spectrum line transmissions quickly and precisely (five or more lines a minute).

JARRELL-ASH
Company
165 Newbury Street
Boston 16, Mass.

If it's an optical instrument, think of Jarrell-Ash!

Write today for Bulletin describing these instruments — address Dept. M

Base Metal Surfaces

(Continued from p. 122)

heat being dissipated by conduction, and as energy absorption by the atoms which, in turn, increases their potential with respect to their original grouping. The behavior of a surface to applied stress can be summed up as follows:

1. In the initial state, the surface is composed of crystalline material. This surface may be contaminated by the presence of oxides or other products of reaction.

2. Emery bobbing or buffing causes intensive slip to take place, and the surface grains are deformed. Their temperature is raised considerably and a certain amount of energy expended by the bobbing is absorbed by the blocks of atoms which have been forced from their original groupings due to slip, and have taken up new positions.

3. Continued bobbing causes a rise in temperature which, in turn, causes slip to give place to a plastic deformation. A layer of fragmented grain material, with very highly distorted matter interstitially situated between fragments, spreads itself along the surface in the direction of the applied stress.

4. Final polishing causes the extreme surface of the layer to become very smooth by reason of localized compacting action with a resulting surface of high brilliancy.

SURFACE PREPARATION

A fabricated (rolled, drawn, extruded, cast, forged, machined) metal surface is a complex zone, and the production of a polished finish prior to electrodeposition is influenced as much by the state of the material as delivered to the plater as by the actual processing producing the polish. He must accept this surface without being even aware of its condition, and on this unknown and possibly very unsatisfactory foundation he must proceed to effect a polish of the order required to accept a smooth and even deposition. The point is that the surface and subsurface metal are in a state of high internal stress due to the severe previous treatment.

In order to make this viewpoint clear, the following experiment was carried out:

1. A machined part was polished until it appeared smooth and lustrous.

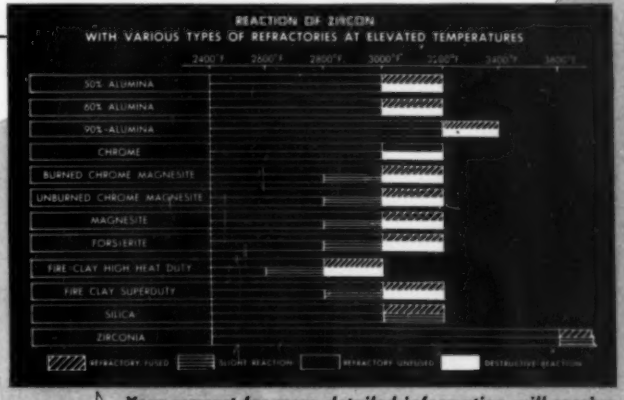
2. Half of the component was

(Continued on p. 130)

Using the properties of ZIRCON AND ZIRCONIA to advantage

The unique super refractory properties of Zircon and Zirconia have particular utility where resistance to extremely high temperatures or unusual fluxing conditions often make it desirable to use these materials, in minimum thickness, in combination with less expensive back-up material.

Determination of the temperature ranges within which contact between these super-refractories and the back-up materials are practical, is of primary importance.



● Charted here is the reactivity in the temperature range from 2400°-3600°F

Your request for more detailed information will receive the immediate attention of our New York Office.

TAM PRODUCTS
Registered U. S. Pat. Off.

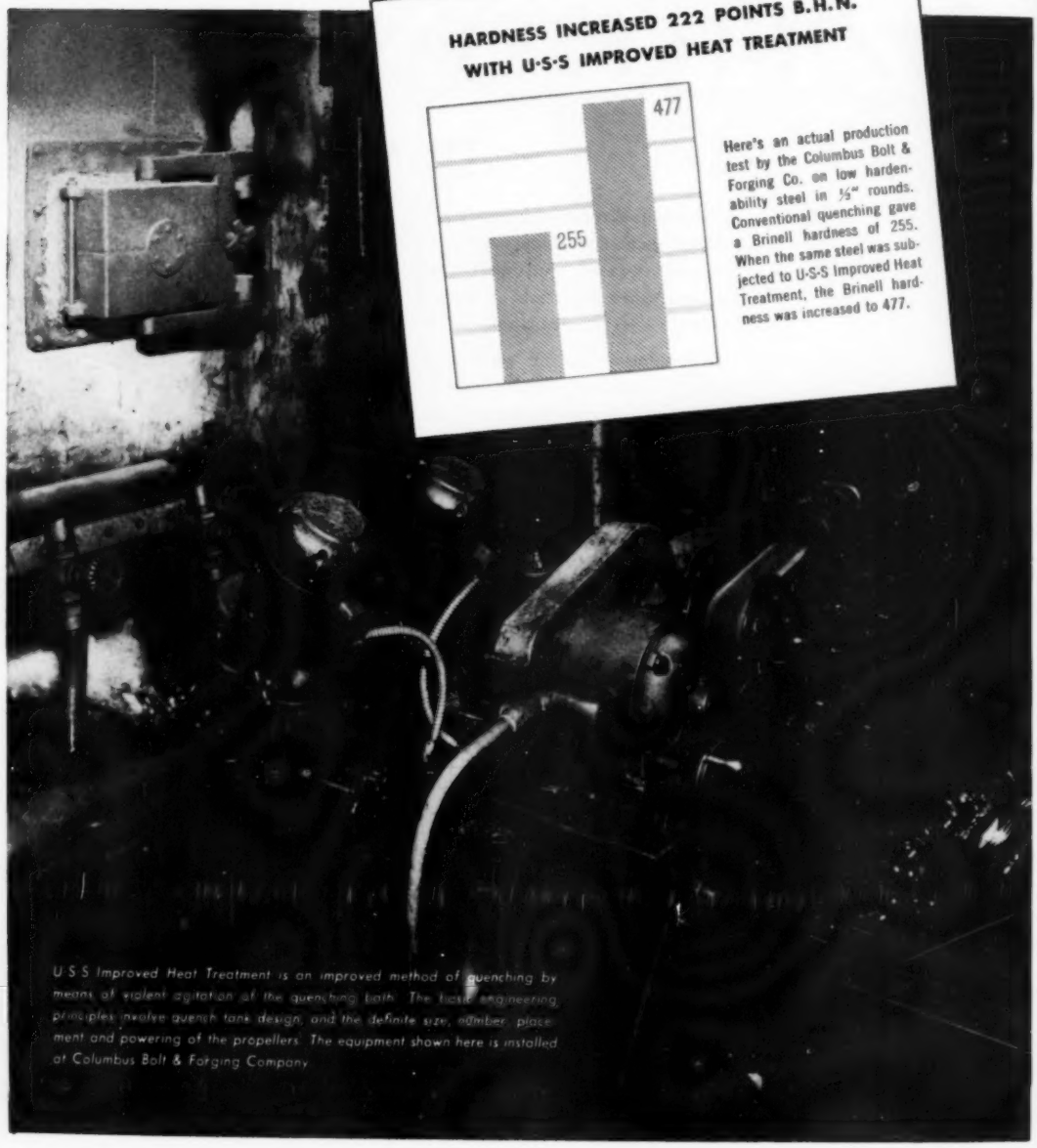
TAM is a registered trademark.

TITANIUM ALLOY MFG. DIVISION
NATIONAL LEAD COMPANY

Executive and Sales Office: 111 BROADWAY, NEW YORK CITY · General Offices, Works, and Research Laboratories: NIAGARA FALLS, N. Y.

HOW TO GET THE MOST OUT OF

—keep a sharp eye



HARDNESS INCREASED 222 POINTS B.H.N. WITH U-S-S IMPROVED HEAT TREATMENT

Here's an actual production test by the Columbus Bolt & Forging Co. on low hardenability steel in ½" rounds. Conventional quenching gave a Brinell hardness of 255. When the same steel was subjected to U-S-S Improved Heat Treatment, the Brinell hardness was increased to 477.

U·S·S Improved Heat Treatment is an improved method of quenching by means of violent agitation of the quenching bath. The basic engineering principles involve quench tank design, and the definite size, number, placement and powering of the propellers. The equipment shown here is installed at Columbus Bolt & Forging Company.

THE ALLOY STEEL YOU'RE GETTING on quenching methods

TODAY, as critical alloying elements become scarce, all users of alloy steel are faced with the necessity of getting the most out of the steel they're receiving.

In most cases, this puts the problem squarely up to the heat-treater. Better heat-treatment methods can often do the job.

If you encounter difficulties, don't be too quick to blame the steel or the heating practice. The answer may be better *quenching* methods. More specifically, your problem might be solved with U·S·S Improved Heat Treatment — a superior quenching technique developed by United States Steel.

U·S·S Improved Heat Treatment extracts heat rapidly and *evenly* from every part of the material's surface. This treatment assures accurate timing, allowing removal of the material from the quenching bath while a certain amount of residual heat is present. Elapsed time from quench to tempering treatment is held to an absolute minimum. This not only improves mechanical properties; it also reduces cracking. And, this quenching method improves machinability by minimizing the formation of free ferrite in hypo-eutectoid steels.

The use of this quenching process is available to you without charge.

United States Steel does not manufacture or sell heat-treating equipment, but our metallurgists will be glad to analyze your heat-treating methods and make suggestions that may give you more uniform hardness, less rejects and less retreatment.

UNITED STATES STEEL COMPANY, PITTSBURGH
COLUMBIA STEEL COMPANY, SAN FRANCISCO
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM
UNITED STATES STEEL SUPPLY COMPANY
WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

Comments on U·S·S Improved Heat Treatment

by Mr. R. E. Christin, Chief Metallurgist
Columbus Bolt & Forging Co., Columbus, Ohio

"Quenching is a process often neglected in heat treatment. We feel it is just as important (if not *more* important) than any other phase of heat treatment. There is a tendency to concentrate too much on the heating—and lay too much blame for failure to the heating—when proper quenching could produce the objectives desired. Heating, even in the ideal environment, can be inadequate if quenching is faulty.

"Before we installed U·S·S Improved Heat Treatment, we occasionally encountered hardness variations in the as-quenched condition. These variations were loosely attributed to either the steel, or the heating or the quenching. However, after adopting the U·S·S agitated quench process, these hardness variations were practically eliminated, obviously indicating that conventional quenching was the chief cause of the hardness variations.

"After seven years' experience with U·S·S Improved Heat Treatment, we are convinced that this method is the answer to most hardening problems."

Carilloy Steels

ELECTRIC FURNACE OR OPEN HEARTH

COMPLETE PRODUCTION FACILITIES IN CHICAGO OR PITTSBURGH

1-933

UNITED STATES STEEL

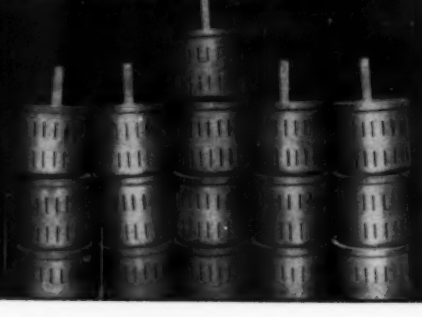
FAHRITE

heat-resisting castings for unusually high temperatures

In the most severe applications, where thermal shock is greatest, you'll find rugged, economical FAHRITE castings giving top-notch service. There are grades of FAHRITE for many conditions. You can rely on the recommendations our engineers will make.

THE OHIO STEEL FOUNDRY CO.

SPRINGFIELD, OHIO · Plants at Lima and Springfield, O.



52100

STEEL TUBING and BARS

Tops for:

- ★ HARDNESS
- ★ LONG WEAR
- ★ TENSILE STRENGTH
- ★ MACHINABILITY

. . . And tops for use in a long list of machine parts and tools.

Over 200 tube sizes from .898" O.D. to 8.250" O.D. Bar sizes from .171" round to 7.5" round. Also Ring Forgings.

Write for a copy of our latest stock list today.

PETERSON STEELS, INC.

DEPT. M, 82 POINIER STREET, NEWARK 5, N. J.

Telephone: Bigelow 3-2324

DETROIT, MICH. • CHICAGO, ILL.

Single Polisher

No. 53-450

EBERBACH METALLOGRAPHIC POLISHERS

For preparation of fine metallographic specimens — the sturdy, smooth operating mechanism is carefully balanced for long life. A sixth H.P. motor turns the polishing wheel through a speed-reducing, torque increasing V-belt drive at speeds of 500, 650 or 800 r.p.m. Write for Bulletin 90-I.

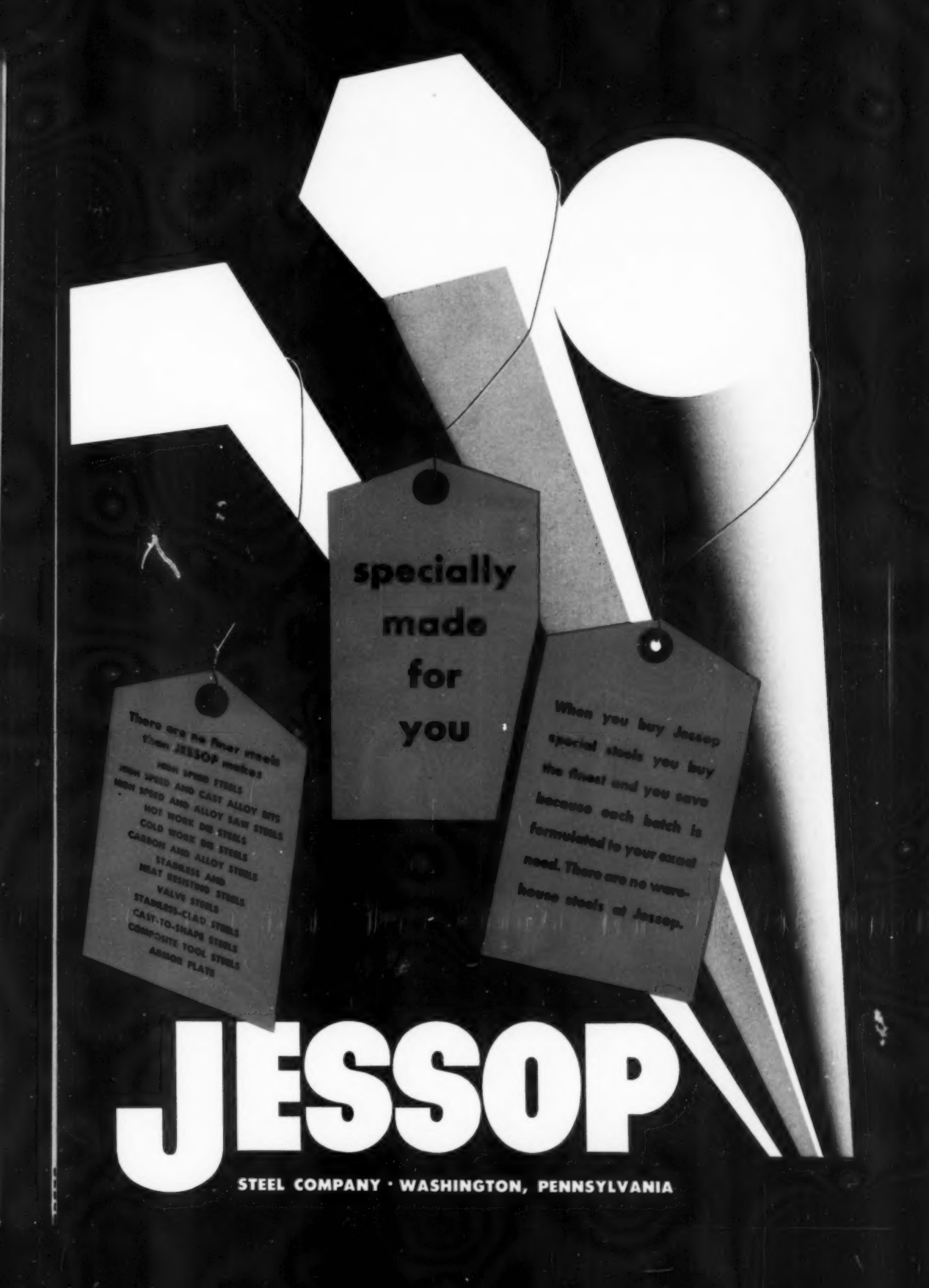
Eberbach CORPORATION

SCIENTIFIC INSTRUMENTS & APPARATUS

ESTABLISHED 1940

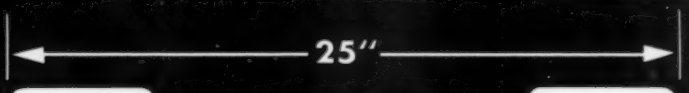
ANN ARBOR, MICH.

Telephone 2-5634 Teletype ANN 776


specially made for you
When you buy Jessop special steels you buy the finest and you save because each batch is formulated to your exact need. There are no warehouse steels at Jessop.
There are no finer steels than JESSOP makes
HIGH SPEED STEELS
HIGH SPEED AND CAST ALLOY BITS
HIGH SPEED AND ALLOY SAW STEELS
HOT WORK DIE STEELS
COLD WORK DIE STEELS
CARBON AND ALLOY STEELS
STAINLESS AND HEAT RESISTING STEELS
VALVE STEELS
STAINLESS-CLAD STEELS
CAST-TO-SHAPE STEELS
COMPOSITE TOOL STEELS
ARMOR PLATE
JESSOP
STEEL COMPANY · WASHINGTON, PENNSYLVANIA

For Aluminum Die Casting

The NEW LESTER-PHOENIX HP·1·C

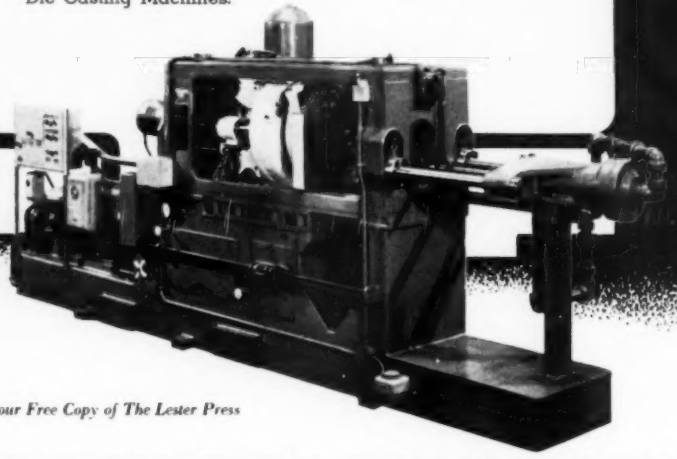


DIE MAKER'S PRECISION

Like all Lester-Phoenix machines, the NEW HP-1-C has been designed to give you maximum production —day in, day out; year after year. The unsurpassed precision of the NEW, high speed, HP-1-C machine means higher quality die castings, longer die life, and flash-free die locking.

The shot cylinder and cold chamber are accurately supported in perfect alignment in either of two shot positions. There is no binding of the shot plunger and full pressure is delivered to the die. The solid frame is likewise finished to within .0005" with die maker's precision. And, for maximum use, the new HP-1-C is convertible to the famous Self-aligning Zinc End.

These are the highlights of the new HP-1-C. The representative listed below in your area will be happy to explain all the features of this and other Lester-Phoenix Die Casting Machines.



Write for your Free Copy of The Lester Press

LESTER-PHOENIX DIE CASTING MACHINES

REPRESENTATIVES

New York	Steven F. Krauld	Cincinnati	Index Machinery Corp.
Detroit	Thoreson-McCosh	Los Angeles	Seaboard Machinery Co.
Chicago	J. J. Schmidt	San Francisco	J. Fraser Rae
Cleveland	Don Williams	St. Louis, Milwaukee	A. B. Geers
		New England	Kavanagh Sales, Inc.

FOREIGN

Toronto, Canada	Modern Tool Works, Ltd.
London, England	Dowding & Doll, Ltd.
Calcutta, India	Francis Klein & Co., Ltd.
Sydney, Australia	Scott & Holladay, Ltd.
Japan, New York	W. M. Hewitt, Inc.

distributed by LESTER-PHOENIX, INC., 2619 CHURCH AVENUE • CLEVELAND 13, OHIO

WHERE TANKS ARE BUILT

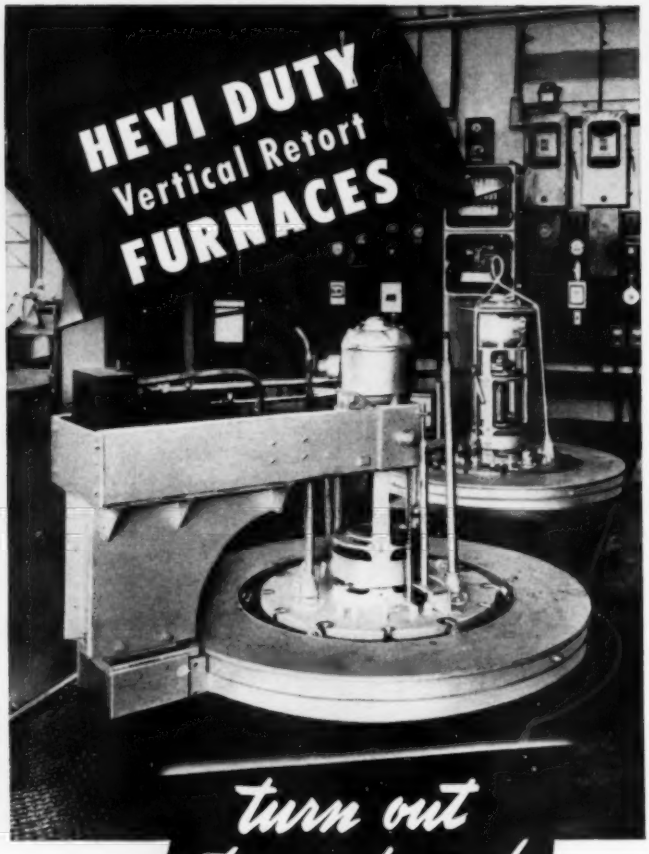
ARMOR-ARC *is the accepted Electrode*

Armor-Arc B .....307 Lime Coating for DC welding
Armor-Arc C .....307 Lime Coating for AC welding
Armor-Arc MN...307 AC-DC Coating
Armor-Arc MO...308 AC-DC Coating

ALLOY RODS CO.

6007 W. MARKET STREET • YORK, PA.

Alloy Rods Co. YORK, PA



turn out tons of work
require a minimum of floor space

New plant space is expensive. That is why the Hevi Duty vertical retort furnace should fit into your program of expansion of production heat treating facilities. It is economical—turning out tons of work in a minimum floor space, flexible—the same furnace can be used for most major heat treating operations such as Carburizing, Nitriding, Dry Cyaniding, Bright Annealing and Clean Hardening. Information which will interest you is in Bulletin HD-646—send for it—today

HEVI DUTY ELECTRIC COMPANY
HEAT TREATING FURNACES HEVI-DUTY ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS
MILWAUKEE 1, WISCONSIN

Base Metal Surfaces

(Continued from p. 124)

protected by waxing.

3. The unprotected part was etched in sulphuric acid.

4. The wax was removed, and the whole component cleaned.

The specimen was then plated for 35 min. with dull nickel and sections of the polished half and the etched half were cut for metallographic examination. Metallographic examination showed that polishing had not improved the distorted nature of the surface layer. The emery bobbing had augmented the fragmentary nature of the layer by causing it to spread completely along the substrate surface and, at the same time, had compacted it into a shallower depth. The interface looked good from the manner in which the deposit grew, but the adhesion of the contacting metals was far from satisfactory.

The interpretation of interfacial conditions, especially when assessing the degree of adhesion of the electrodeposited layer, is far from easy. A deposit may develop along apparently satisfactory lines but the essential property of excellent adhesion may be absent, although the section of the plating may appear featureless. Selective examination will often reveal that an apparently sound example of deposition will exfoliate in a very easy manner. This is due entirely to the behavior of the surface, and cannot be associated with any discrepancies on the plater's part.

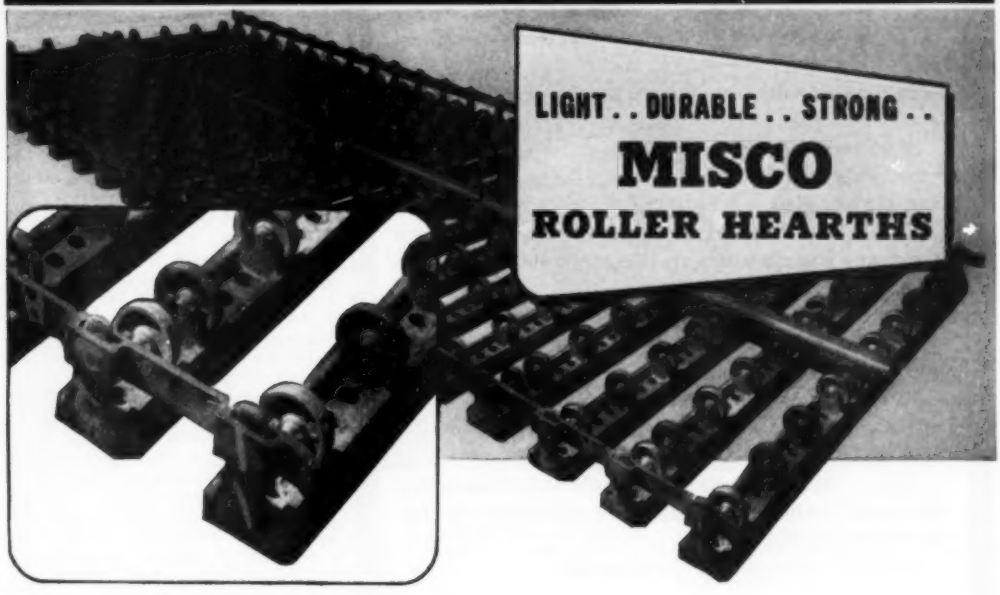
CHARACTERISTICS OF POLISHED SURFACES

Three conditions present in the base metal surface which can be considered as detrimental to electrodeposition are: *(a)* presence of minute cracks which penetrate the depth of the layer; *(b)* presence of minute voids (or bridging) which gives rise to a porous condition; *(c)* the very poor adhesion possessed by the layer, both in its own thickness, due to stratification, and at its extreme depth where it joins the crystalline material.

The minute cracks which extend from the upper extremity of the layer inward, often penetrating as deep as the layer itself, are the electrodepositor's chief bugbear. These cracks are so fine that they act as retaining capillaries for cleaning fluids, acids, or bath solutions.

(Continued on p. 132)

MISCO HEAT RESISTING ALLOY ROLLER HEARTHS



MISCO ROLLER HEARTHS are used extensively as a means of conveying work through heat treating furnaces. They are designed to distribute substantial loads over smoothly operating rollers so that movement is accomplished with minimum effort. Component parts are light, durable and extremely simple. By varying the width and number of units, an assembly can be arranged for any size furnace. Consult Misco on your high temperature needs. Our wide experience in practical design is at your service, and you can depend on maximum endurance from Misco heat resisting alloy products.

SPECIFY MISCO Heat Resisting Alloys—*CAST and ROLLED*—For all Heat Treating Equipment

Furnace Parts • Roller Rails • Roller Hearths • Conveyor Rolls • Trays • Retorts • Chain • Muffles • Walking Beam Conveyors • Carburizing and Annealing Boxes Dipping Baskets • Cyanide and Lead Pots • Thermocouple Protection Tubes • Pickling Equipment • Centrifugal Castings • Miscellaneous Castings and Rolled Bars • Sheets, Plates, Tubes, Nuts and Welding Rod for use at high temperature or under corrosive conditions.

ALLOY CASTING DIVISION
Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys

1998 GUOIN STREET • DETROIT 7, MICHIGAN

OVER ONE HUNDRED YEARS OF CONTINUOUS SERVICE. ROUNDS, SQUARES, FLATS, HEXAGONS, OCTAGONS

BILLETS AND FORGINGS FOR PRODUCTION, TOOL ROOM AND MAINTENANCE REQUIREMENTS.

Making
BEST USE OF AVAILABLE STEEL

In times of emergency, substitutes can often be used to good advantage.

Right now, the urgent requirements of production for national defense are taking the lion's share of high-grade alloying materials.

That is as it should be, of course. But the fact remains that many manufacturers are being confronted daily with knotty problems of production.

Frequently these difficulties can be solved by using substitute grades or alternate methods of manufacture and treatment.

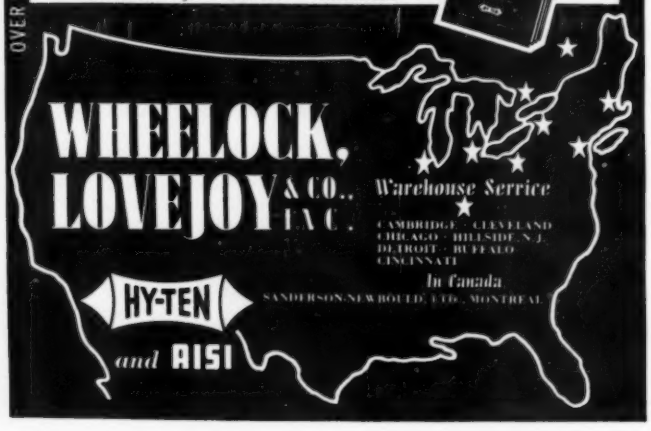
To help you decide *which* substitute grades you can use and *how* you can use them most effectively, call on our staff of metallurgical experts.

A letter – or a phone call – will focus Wheelock, Lovejoy's specialized technical skill and long experience on your individual problems.

And we'll be delighted to be of service.

Write today for your FREE COPY of the Wheelock, Lovejoy Data Book, indicating your title and company identification. It contains complete technical information on grades, applications, physical properties, tests, heat treating, etc.

134 Sidney St., Cambridge 39, Mass.
and Cleveland • Chicago • Detroit
Hillside, N. J. • Buffalo • Cincinnati



Base Metal Surfaces

(Continued from p. 130)

which, in a sense, charge the layer with reactive fluids. Even careful rinsing will not eliminate these trapped fluids. Their presence will not prevent effective plating; it is during the storage stage or in service life that the trapped fluids manifest their presence. During final polishing prior to a light decorative chromium deposition on dull nickel, the heat generated by the buffing raises the temperature of the retained fluids and an accelerated reaction with the base metal is begun. This extends along the interface between the substrate metal and the deposit, thus undermining the adhesion and causing eventual exfoliation of the deposit.

Many a plater has congratulated himself on a well-executed job, only to find that the plate sheds itself after a short period of service life; and yet, he cannot associate this trouble with any neglect on his part. A condition of this nature often takes place because the surface has been overpolished.

The presence of voids in flowed layers due to bridging results in a similar condition. Polishing compound can be retained which fills up the gaps left by the thin bridges of flowed material and the layer can be described as a metallic body with zones of nonmetallic (and nonconductive) material distributed throughout its extent. This condition also results in loss of continuous adhesion between the base metal and the deposit. If this is prevalent throughout the interfacial zone, blistering will result because the localized concentrations of reactive matter will produce bulky products which literally lift the deposit bodily in their vicinity.

Stratification of the surface layers is found wherever work hardening has taken place, and is common to all forms of bearing surfaces quite apart from those produced by polishing. The effect of such a formation on the electrodeposit is indirect; the layer itself is adherent but its own structure is weak. So, when a plated layer peels off, it occurs because the surface of the base metal itself has been shed, in spite of its firm adherence to the superimposed deposited metal. The reason for such behavior lies in the character of the flow layer itself.

The properties of a metal should be fairly well known before any final polishing is done prior to

(Continued on p. 134)

You can make important savings in fuel by taking advantage of the quick heating characteristics of J-M Insulating Fire Brick. These light-weight brick permit a quicker rise to proper operating temperature in the furnace because of their low heat storage capacity, and low thermal conductivity. Where furnaces are being intermittently operated these are two especially important characteristics.

These same insulating materials can also be obtained in large size units called Johns-Manville Insulating *Fireblok*. This product has many advantages over the smaller size fire brick for certain types of jobs . . . from both a construction and stability standpoint. The Fireblok units can be quickly applied because they are easy to cut and fit. Fireblok insulations provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

It will pay you to let a Johns-Manville insulation engineer explain the many ways in which you can save by using these insulations in your furnaces. Just write for further information to Johns-Manville, Box 290, New York 16, N. Y.

JM

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage†, percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2,000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.40
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

†24-hr. simulative service panel test for JM-3000; 24-hr. soaking period for other brick.

*Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures.

Note: Above tests are in accordance with A.S.T.M. tentative standards.

Johns-Manville *first in* **INSULATIONS**

METAL POWDERS

-IRON
-NICKEL
-SILICON
-MANGANESE

PLASTIC METALS is one of the leading metal powder producers in the world, with 17 years of experience making powder for use in the fields of powder metallurgy, electronics, chemistry and many others. If you are interested in:

- **REDUCING COSTS**
- **INCREASING OUTPUT**
- **CONSERVING CRITICAL METALS**
- **IMPROVING QUALITY**

Consult us regarding the advantages of powder metallurgy, or about any problems which you may have relating to metal powders.

PLASTIC METALS
DIVISION OF THE NATIONAL RADIATOR COMPANY
JOHNSTOWN, PENNSYLVANIA

Base Metal Surfaces

(Continued from p. 132)

deposition. It should be ascertained whether the fabricated parts are annealed or are in the as-drawn or hard condition. For example, during annealing, the uppermost layer of a surface rarely completely recrystallizes unless the material is held for very protracted periods at the softening temperature. This results in the existence of crystalline and fragmented material lying side by side. Hence, if annealed material has been supplied, it is good practice not to overpolish it if a surface amenable to electrodeposition is to be maintained.

AMENABLE SURFACES

If a surface is bounded by a layer composed of highly disordered matter, the condition for crystal building is likely to be remote. Fundamentally, for a surface to exhibit ideal adhesion of a deposited layer, it must possess an equivalence of atom retention throughout. This would be a definition of an "amenable" surface.

When a surface is polished, it becomes an area of minute zones of unequal energy content (or stress), or an area of differing potentials throughout its extent; the degree of reactivity of this surface varies from point to point. When ions arrive at such a surface, they will be captured first by the zones of minimum energy content, and, having been captured, will form centers on which deposition can continue.

If we could ascertain the conditions present at these points, and reproduce such conditions throughout the surface, we should, in effect, have equipotential conditions and the surface would accept ions at an equal rate throughout.

Another attribute of an amenable surface must be emphasized. A surface which possesses the property of equivalent capture of ions automatically produces a smoothing action. Equal amenability does not induce deposits to fill large cavities and so build up a level deposit; it confines its action to the very early stages of deposition, and causes the minute irregularities of a surface to be filled before any deposition is effected on the high points of the surface. Thus, in the first few seconds of deposition, ion capture takes place in these irregularities and so builds up the deposit until

(Continued on p. 136)

Aluminum SMOKE RINGS.....

Type EMD-2 complete with optical system, power supplies, vacuum system, and control panel. Features include: choice of optics to suit application; 5-control specimen positioning; ports for accessories; built-in charge neutralizer; antihalation beam stop; direct-viewing fluorescent screen; built-in 3-plate camera (4" x 5"); multiple specimen holders; high-speed electromechanical valving.

A diffraction pattern of metallic aluminum by

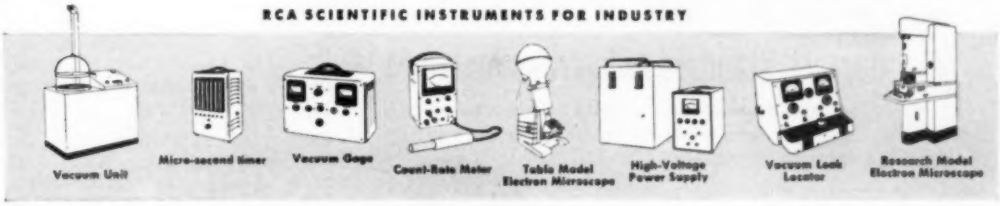
the RCA Electron Diffraction Unit, Type EMD-2!

THIS pattern reveals fundamental facts about the crystalline structure of an ultra-thin film of aluminum. The pattern was produced in an RCA Electron Diffraction Unit by bombarding the specimen with a beam of electrons—then capturing the diffraction pattern with a camera built right into the unit itself!

This instrument is unsurpassed for producing reflection and transmission diffraction patterns from micro-quantities of materials, surfaces, and monomolecular layers. Type EMD-2 makes it possible to distinguish between structures, or forms of materials, which have the same chemical composition but differ physically. In a matter of seconds it can produce clear, brilliant patterns of matter present in quantities too minute for X-ray diffraction. *It is the only means known for examining the atomic structure of true surfaces.*

Type EMD-2 is effective in work with metals, ceramics, plastics, organic films, biologicals, etc. Its usefulness for investigating corrosion, catalysts, lubricants, surface deposits, graphites, and pigments is well established. For complete data, write Dept. S-101, RCA Engineering Products, Camden, N. J.

RCA SCIENTIFIC INSTRUMENTS FOR INDUSTRY



SCIENTIFIC INSTRUMENTS
RADIO CORPORATION of AMERICA
ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

"HERE IS 4,500 cubic feet of gases FOR METAL TREATING!"

Barrett* Standard Anhydrous Ammonia

When dissociated, one 100-pound cylinder of Barrett Standard Anhydrous Ammonia (Refrigeration Grade) yields 4,500 cubic feet of mixed gases—approximately 3,400 cubic feet of pure hydrogen and 1,100 cubic feet of pure nitrogen.

You effect real economies when you use Barrett Standard Anhydrous Ammonia as a replacement for other more expensive sources of hydrogen and nitrogen.

Engineers have obtained many advantages from the use of dissociated ammonia as controlled atmosphere in furnaces for bright annealing, clean hardening, copper brazing, sintering, reduction of metallic oxides, atomic hydrogen welding, radio tube sealing and other metal treating practices. Anhydrous ammonia also has unsurpassed qualities in the nitriding of steel, used as ammonia gas or dissociated.

The advice and help of Barrett technical men are available to Barrett customers without charge.

Barrett* Standard Anhydrous Ammonia

In 150, 100 and 50-pound cylinders for fast delivery from a stock point located near you. And in tank car shipments from Hopewell, Va., and South Point, Ohio.

THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 RECTOR STREET, NEW YORK 6, N. Y.

America's Leading Distributor of AMMONIA

Barrett*

*Reg. U. S. Pat. Off.

Base Metal Surfaces

(Continued from p. 134)

the high points are reached when it becomes smooth and level. This property of such a surface is fundamental; a very useful attribute which should have far-reaching results in the technique of successful electrodeposition.

The establishment of a completely adhesive layer in the first few seconds of deposition will assure the building up of a homogeneous plate which will be sound and free from porosity, either in the form of minute cavities or actual pores which extend from the substrate surface throughout the thickness of the plated layer. These unwanted pores are produced within the first few seconds of deposition, and are present due to surface influence. Gases have very little or nothing whatever to do with their existence, as shown by the fact that a surface can be prepared which will produce many of these minute voids throughout the deposition, at will, for example, by the "to and fro" type of polishing which causes waves of surface flow. An examination of several hundred specimens containing pores has shown that these defects were generated from a "peak" on the surface of the basis metal.

The behavior of deposits on polished surfaces indicated that such a surface was far from a satisfactory foundation on which to build up an adherent electrodeposited layer. Comparisons of deposits on finely machined surfaces, ground surfaces, emery polished and tripoli polished surfaces, and on those which had been well flowed by excessive polishing gave extraordinary results. Finely machined and the ground surfaces accepted more or less continuous plating, while the emery and tripoli polished counterparts did not display such continuity; and the excessively polished type revealed a very indifferent deposition. This state of affairs immediately suggested that the absence of flowed layers of surface metal greatly facilitates continuous deposition.

Of course, the deposit must be fairly level or it will merely duplicate every base surface defect in its own surface. The behavior of the different surfaces pointed clearly to the fact that such conditions could be realized, but only by a combination of pre-smoothing of the surface followed by an attempt to produce equipotentiality throughout

(Continued on p. 138)

metal show facts

National Metal Exposition

NATIONAL METAL CONGRESS
WORLD METALLURGICAL CONGRESS • Oct. 15-19 • Detroit, Mich.

The free world fights back

American history is filled with outstanding exhibitions of sheer, raw courage. But, courage doesn't carry a "Made in America" label.

There's a special kind of courage . . . the kind that enables little nations to rebuild bomb-wrecked cities and plant again war-scarred fields and find the inner strength to lift a defiant resistance against a new and far more powerful enemy.

Most of us feel that the token forces the UN allies have sent to Korea are thoroughly inadequate. They are — for us. But if in one quarter-century our young men had been decimated, if in that time our economy had been shattered by two world wars . . . we might have a different angle on what war really means.

Making up for manpower and equipment, the smaller free nations are fighting back with us in every way they can . . . with men, metals and science. What metal experts and metal scientists have been doing abroad in these years of unrest since '45 will be aired at the National Metal Exposition and its co-starring event, the World Metallurgical Congress. We'll get a chance to see and hear the men who lead the free world's resistance against the new and mighty aggressor . . . we'll get a chance, perhaps, to get a better slant on what the common needs are against the common foe.

Standing virtually alone as an arsenal for the free world . . . America needs every helping hand it can get to build not only more arms and better arms . . . but a better understanding of its allies, too. That understanding will in many ways make international history October 15-19. You'll not want to miss it.

DEFENSE BUSINESS

Full Steam Ahead

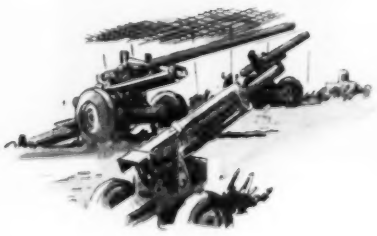
There's plenty of evidence that the last half of '51 will see military orders rolling in high gear — doubling and maybe tripling the volume of the first six months. That means business, lots of it. It means faster production schedules. It means 'round-the-clock shifts. It means literally **thousands** of big and small industries will need more and better equipment of every kind to get the job done on schedule. It means more and bigger sales of every kind of metal fabricating **machinery** . . . of every kind of metal . . . of every kind of metal working, preserving and handling product.

Where will the military suppliers be looking for just that kind of new equipment? Well, they'll look *FIRST* and *LONGEST* at the **National Metal Exposition** — and why not? That's where the aggressive, slugging-for-sales outfits will be showing the newest and finest in their lines. That's where **brand-new** sales-getters will be unveiled and that's where competition will get its first big jump against the field. When you're showing before a tremendous and deeply interested audience with a checkbook in its collective hand . . . you're sure to get your **share**!

It's taken a long time for defense business to get rolling, but trial under fire in Korea has given our forces exactly what was needed . . . a chance to test weapons and equipment under actual war conditions. Now that they know what they want, the men charged with rebuilding our armed might will be on the ball. That's why the more alert and the most aggressive companies in the land will be showing at the National Metal Exposition. It's the big league of American **production** and it'll pay off in bigger sales.

The Greatest Metal Exposition Ever!

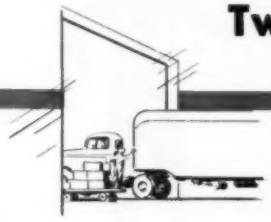
Big things like this just don't happen . . . they're the result of long and careful planning and intensive effort. To make sure *this* would be the *biggest* . . . the *finest* . . . the *most productive* Metal Show ever staged, a whole lot of study went into timing it to coincide with what was expected to be the peak of defense business . . . or at least, the peak of defense business interest among the nation's industries. Take a look at what the military needs are going to be in the year ahead . . .



- Thousands of tanks . . . motors for those tanks . . . all sorts of gear to equip them . . . guns and gun mounts . . . treads and escape hatches. Big, tough fabricating jobs, every one of them.
- Shells by the millions . . . shell cases . . . shell fuses, etc. Grenades, flame throwers, mess kits and bayonets. Trucks and self-powered howitzers. Special metals, special handling, with big orders.
- 'Planes by the thousands, fighters . . . bombers . . . transports. The machining and fabricating of light metals will be a subject of keen interest at the Metal Show.
- Behind-the-lines equipment will include almost everything from belt buckles to bomb handling trucks. Thousands of items, each with a demand for special equipment and know-how. The Metal Show will be a source of immense benefit to such manufacturers.
- Naval needs . . . from battle-wagons to barges . . . from guns to galley equipment. Spec and order holders will be searching the Metal Show for the kind of fabricating products that will help them do a better job . . . faster and cheaper.

That's the sort of thing that'll make this the biggest and best Metal Show ever. Widespread interest in everything from new alloys to new shipment handling equipment. Eager buyers trying to get their outfits set to handle the tremendous volume that will be rolled up on military needs. Industrial expansion is an accepted part of today's good business volume . . . but it'll likely be a poor fourth to the immense demand of existing industrial capacity for replacement machines . . . for newer processes and faster methods. If you've got what it takes and you've got it in the front row of the biggest Metal Show in history . . . you'll sell a whopping share of your capacity to produce!

Get in – Get out Problem Eased by Two Full Weeks for Installation



Michigan State Fairgrounds

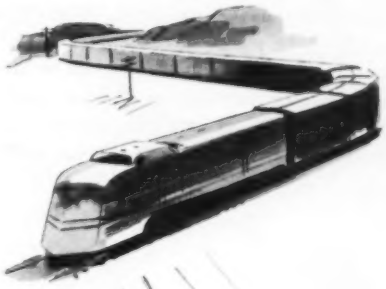
Exhibitors at the biggest National Metal Exposition ever staged are going to like what they see when they arrive at the spacious layout of big buildings, ample parking facilities and general smartness of the Michigan State Fairgrounds. They'll like the neatness, the well-kept grounds and the fine structures, but they'll be tickled pink over the manner in which trucks and truck-trailer units can maneuver easily to unload heavy exhibits right at the doors of the buildings where they'll be shown . . . they'll appreciate the wide doors, the broad aisles, the good lighting and the carefully planned layouts.

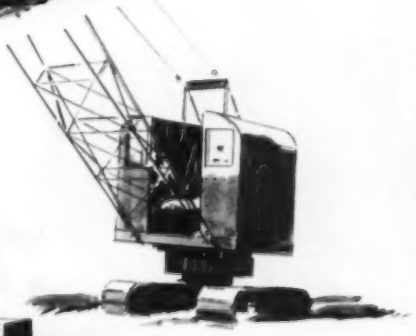
Getting into this biggest Metal Show will be a cinch and a money-saver, too. Two full weeks of make-ready time are scheduled to duck heavy overtime costs and to keep to a minimum the necessary charges that go along with any really attractive, sales-provoking display. Getting out after the big Metal Show closes will be easier and faster, too.

. The Michigan State Fairgrounds is located right off main highways and on the rail spurs. Wide, well-paved roadways lead from building to building and from railheads to buildings. There'll be plenty of power equipment to get you loaded out and keep things moving.

More than ever before advance planning will pay off in time and money saved for every exhibitor. Ideal for the type of show being staged and big enough to give every exhibitor and every man attending the Show elbow room, this site offers so many advantages over some of the halls and auditoriums the Metal Show has occupied that it rates a cheer from every participant.

However . . . you'll have to plan, too. Get set now to get to the grounds early enough to get your exhibit set up and working. Plan ahead for getaway day and you'll side-step the usual last-minute headaches!





SPECIAL SERVICES

specially for you

Exhibitors will find many little details arranged for their comfort and convenience at this biggest Metal Show. Washrooms and water fountains dot the grounds . . . there'll be centrally located public 'phone booths and pages to deliver telephone calls and telegrams and keep you informed as messages come in. There'll be adequate parking places for exhibitors. Information centers will supply needed aid to customers hunting up your display. Special express busses will stop and depart from nearby vantage points. There'll be a first-aid station where minor repairs will be made and the more common remedies dispensed. There'll be uniformed guards to protect exhibits, govern crowds and keep traffic flowing.

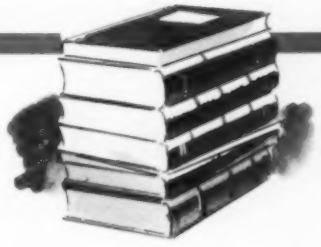
You can help the service by leaving information in your booth whenever you leave for a few minutes or when you leave the grounds.

A restaurant is planned on the grounds where you can get that quick cup of coffee or a full meal if you wish. Soft drinks and cigarette-vending machines will be handy, too. There'll also be a check-room where you can park your bags, wraps or whatever else you feel needs the special protection of checking.

Your suggestions as to how ASM may better service the Show will be gratefully received . . . for only by matching our services to the calibre of this great Show will fullest co-operation and convenience be maintained.

Did you know *This* about

AMERICAN SOCIETY FOR METALS?



is the largest group of metal engineers in the world?

is 35 years old and has expanded from 12 members to over 20-thousand members?

has 16-thousand members who are fabricators of metals and four-thousand members who manufacture ferrous and nonferrous metals?

is recognized as the engineering society of the metals industry?

held the first meeting in the fall of 1913 at the Fellowcraft Club in Detroit?

has had the same continuing management from its inception to the present time?

has not increased its annual dues of $10.00 during its entire life?

has an annual budget of approximately one-million dollars?

collected, edited, printed and distributed, in 1950, over 100-million pages of engineering information on the subject of metals?

is the largest publisher of books for the metals industry in the world?

published at a cost of a quarter of a million dollars a METALS HANDBOOK recognized as the bible of the metals industry?

is the publisher of METAL PROGRESS, recognized as the "Fortune" magazine of the metals industry?

publishes the METALS REVIEW, which contains an annotated survey of engineering, scientific, and industrial journals and books in America and abroad received during each previous month?

publishes TRANSACTIONS, which contains all the technical papers presented at its conventions?

owns and operates the National Metal Exposition, the largest annual industrial exposition held in America?

is the sole sponsor of the World Metallurgical Congress to be held in Detroit, October 14th through the 19th, simultaneously with the National Metal Congress and the National Metal Exposition?

will receive at Detroit, during the World Metallurgical Congress, over 600 of the top-level metal scientists of the free world?

at the opening session of the World Metallurgical Congress in Detroit, on October 14th, will present the first complete survey and study made of the metal resources of the world?

acts as consultant on conservation of strategic materials to the United States Navy?

received the Distinguished Service Award from the Ordnance Department in recognition of its services in World War II?

79 chapters hold over 500 meetings a year with annual attendance of 50,000?

New Exhibitors

47

during the last three weeks

A.B.C. Die Casting Machine Co.
Adams Carbide Corp.
Air-Flow Compressor Co.
American Society of Tool Engineers
Anderson Oil Co., F. E.
Anton Machine Works
Boice Crane Co.
Budd Corp., Charles
Cadillac Stamp Co.
Continental Industrial Engineers, Inc.
Diversified Metal Products Co.
Dow Chemical Company
East Shore Machine Co.
Eaton Manufacturing Co.
Galileo Corporation of America, Inc.
Gray-Grimes Tool Co.
Hammond Machinery Builders Inc.
Hanchett Magna-Lock Corp.
Heppenstall Co.
Howard Foundry Company
Industrial Cable & Sling Co.
Institut Dr. Forster
Kearney & Trecker Corp.
Last Word Sales Co.
Manufacturers Processing Co.
Metal Hydrides, Inc.
Metallurgy, Inc.
Metals Review
Michigan Steel Casting Co.
Mir-O-Col Alloy Co., Inc.
Modernair Corporation
National Industrial Publishing Co.
National Radiator Company
Nox-Rust Chemical Corp.
Plastic Metals Division
RCS Tool Sales Corporation
Ransburg Electro-Coating Corp.
Rapids-Standard Co., Inc.
Richards Co., J. A.
Trerice Co., H. O.
Seal-Peel, Inc.
United States Air Forces
Walker-Turner Div.
Warner Division
Wells & Sons, W. F.
Western Sealant of Detroit, Inc.
Weston Electrical Instrument Co.

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

"TRAIN-O-ROLLS"
A Roller Hearth Furnace Mechanism Entirely Within the Furnace Running on Hot Roller Bearings. Roll Widths Reduced 50%. — no holes through furnace wall — permits true atmosphere control — maximum economy.

ENGINEERED ALLOY
Tooling Mechanism, Devices

General Alloys Company of Boston,—"oldest and largest exclusive manufacturers of heat and corrosion resistant castings",—offers a complete design and metallurgical service for any defense purpose, from a jet engine to a 100-foot conveyor furnace, from chemical process equipment to rocket nozzles. Branch offices or representatives in: Baltimore, Buffalo, Birmingham, Chicago, Cleveland, Dayton, Detroit, Fort Wayne, Houston, Indianapolis, Louisville, Milwaukee, Muncie, New York, Philadelphia, Pittsburgh, and St. Louis.

Behind the man who presents this card is a background of thirty-four years of High Temperature and Corrosive Process Engineering. There is no comparable background in our field.

Men of A.S.M. who read M.P. and attend the National Metal Shows are well aware of this background. They know that General Alloys is an *engineering organization*,—not a "foundry". They know that General Alloys pioneered in the production of conveyor furnace mechanism for virtually every major furnace builder and have contributed more original and functional designs to this field than others.

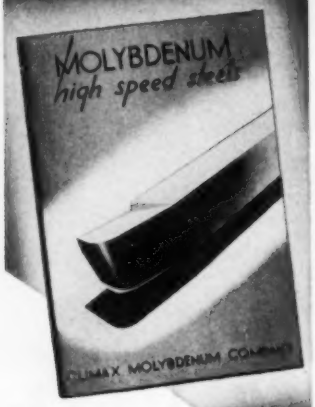
We have for years been conducting the most comprehensive Research and Development of casting process ever undertaken. We *think*, as you do,—as Engineers and Metallurgists. When a General Alloys engineering representative calls by appointment at your plant, he has behind him all that it takes to engineer and deliver a top job in any phase of high temperature or corrosion resistant equipment, tooling or mechanism. Equally important is the fact that *we have learned enough to evaluate our ignorance*,—weigh our own limitations.

P.S.:

"There is NO SUBSTITUTE for EXPERIENCE"
and no alloy experience to compare with G A

NO FURNACE IS BETTER THAN ITS ALLOY PARTS

Its easy to learn to treat Molybdenum High Speed Steel



FREE—this booklet gives all the facts

Data on performance, heat treatment and other authoritative facts are available in our booklet "Molybdenum High Speed Steels".

More and more high speed steel will be of the Molybdenum types which are already giving performance equal to or better than tungsten steel, with economy in alloy content.

Climax Molybdenum Company
500 Fifth Avenue · New York City

Please send your FREE BOOKLET
"MOLYBDENUM HIGH SPEED STEELS"

Name .....
Position .....
Company .....
Address .....

MOLY

MP-7 HS-7

Base Metal Surfaces

(Continued from p. 136)

its area. The best pre-smoothing treatment involves a cutting down of the original surface using an emery bob or a cutting wheel, *but avoiding excessive pressure.* This levels out the surface with a minimum of flow. The grit size must obviously be suited to the state of the original surface.

For example, a rough hot stamping in a 60:40 brass must be well cut down, not only to change the undesirable state of the surface but also to remove the unwanted zone of micro-dezincification which exists just below the roughened exterior. Failure to eliminate this will cause an epidemic of exfoliation and blistering.

After the surface has been cleaned up, it is smoothed with a flour emery to a fine matte luster. This form of surface, if subjected to the action of a weak aqueous solution of phosphoric acid (1¼% with an inhibitor and a wetting agent), will be ideal for excellent adhesion. The object of the etch is not to produce a roughened surface, *but to eliminate areas of high energy content.* Its use affects the surface only at these areas, the zones of lower energy being little or not at all affected.

The various types of deposit have exhibited a tendency to smooth themselves, providing the surface of the base metal is rendered amenable to this action. A very striking example is that of hard-chromium deposition on cast iron cylinder bores or liners. Silver and copper exhibit a remarkable smoothing action, while cadmium shows a superior smoothing than if plated onto a polished or machine-finished surface. Tin and zinc exhibit a far greater continuity of deposit with very little evidence of defects.

ADOLPH BREGMAN

Series-Arc Welding*

WHEN ONE CONSIDERS the fact that welding with normal "Unionmelt" technique involves melting of the base metal and that dilution of

(Continued on p. 140)

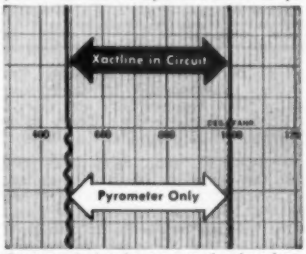
*Abstract of "Welding With Multiple Electrodes in Series — A New Method of Unionmelt Welding", by A. R. Lytle and E. L. Frost, a paper presented at the American Welding Society annual meeting, October 1950.

Automatic
"STRAIGHT-LINE"
TEMPERATURE CONTROL
with
XACTLINE

ELIMINATE
Overshooting
Undershooting

Are you going to continue to put up with that troublesome overshooting and undershooting inherent in your conventional pyrometer control—especially when it is so easy to eliminate that saw-tooth effect?

Put XACTLINE in the control circuit. XACTLINE anticipates the temperature changes—before they occur. And too, it nullifies the varying amounts of thermal lag, residual heat, and mechanical lag—producing a short on-off cycle resulting in "Straight-Line" temperature control. This performance is possible because there is no dependence upon mechanical parts—XACTLINE operates electrically.



Exact reproduction of temperature chart for a heating process showing the comparison of the "Straight-Line" temperature control produced by XACTLINE and the saw-tooth curve obtained with only conventional control.

XACTLINE is applicable to any indicating or recording pyrometer control of the millivoltmeter or potentiometer type. It should be used wherever close temperature control is required—any type of electrically heated oven, furnace, kiln, injection molding machine, and fuel-fired furnaces equipped with motor-operated or solenoid valves.

XACTLINE is a complete unit. No adjustment or coordination with the control instrument is required regardless of the size of the furnace, length of the heating cycle, or size of the load. Installation is very simple—can be either flush or surface mounted.

PRICE **$89.50** F.O.B. CHICAGO
Nothing else to Buy

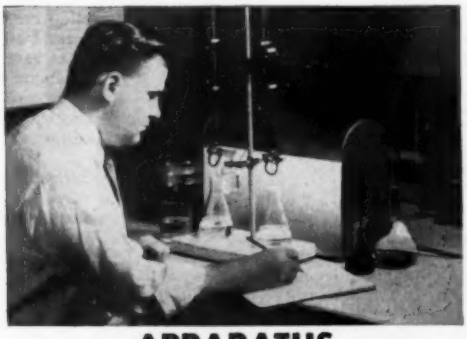
GORDON SERVICE

CLAUD S. GORDON CO.
Manufacturers & Distributors
Thermocouple Supplies • Industrial Furnaces & Ovens
Pyrometers & Controls • Metallurgical Testing Machines
Dept. 15 • 3000 South Wallace St., Chicago 16, Ill.
Dept. 15 • 2035 Hamilton Ave., Cleveland 14, Ohio

WHATEVER LABORATORY NEEDS

Laboratories have at their command from Fisher Scientific Company all of their day-to-day requirements and a large number of modern instruments, apparatus and chemical reagents not obtainable elsewhere.

INSTRUMENTS



APPARATUS

REAGENTS

FURNITURE

Headquarters for Laboratory Supplies

FISHER SCIENTIFIC COMPANY

PITTSBURGH • 717 Forbes (19)
NEW YORK • 635 Greenwich (14)
WASHINGTON • 7722 Woodbury (Silver Spring, Md.)
ST. LOUIS • 2109 Locust (3)
MONTREAL • 904 St. James

♦ ♦ ♦ *Scientific* STEEL IMPROVEMENT

♦ BIG AS THEY COME

♦

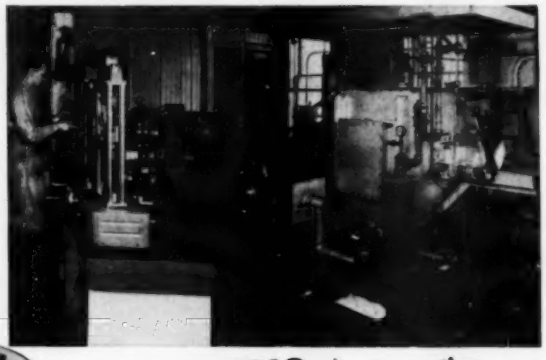
OR BY THE HANDFUL

Our facilities here at Lakeside can handle your job. We provide a most complete scientific steel improvement and metal treatment service. Whether your metal treatment problem is large or small, why not call today.

OUR SERVICES: Electronic Induction Hardening, Flame Hardening, Heat Treating, Bar Stock Treating and Straightening (mill lengths and sizes), Annealing, Stress Relieving, Normalizing, Pack, Gas or Liquid Carburizing, Nitriding, Speed Nitriding, Aerocasing, Chapmanizing, Cyaniding, Dry Cyaniding, Sand Blasting, Tensile and Bend Tests.

THE *Lakeside Steel Improvement Co.*

5418 LAKESIDE AVE., CLEVELAND 14, OHIO HENDERSON 1-9100



Harper

ELECTRIC FURNACES FOR Cementing Normalizing Sintering

Special process furnaces, for research and continuous production of parts requiring hydrogen atmosphere with very low dew points at temperatures reaching 3000°F and above, are designed by Harper Engineers to meet rigid heating requirements.

Shown above is a Harper controlled atmosphere sintering furnace used in the laboratory of a well-known metal products manufacturer for research in powder metallurgy. This Harper furnace plays a major part in the developing and control testing of powdered metals used in production of metal parts of all kinds. Write for information on special process furnaces to meet your rigid heating requirements.

HARPER ELECTRIC FURNACE CORPORATION

39 River St., Dept. 7 Buffalo 2, N. Y.

Series-Arc Welding

(Continued from p. 138)

the weld metal occurs in a minimum amount of at least 20%, a better appreciation can be had of the problem of obtaining a welding electrode composition to compensate for this dilution, particularly in those cases where this dilution may seriously affect the serviceable properties of the deposited weld metal.

Recently a new method of summerged-arc welding has been developed whereby dilution by melted base metal has been reduced to as little as 1½%. This method was described in a paper given during the 1950 American Welding Society annual meeting in Chicago.

The method consists of employing two or more converging welding electrodes connected electrically in series so that the welding current flows from one electrode to the other without utilizing the base metal workpiece as a conductor. Location of the welding zone and amount of heat input to the workpiece are controlled by positioning of the welding electrodes.

With this method of series-arc welding, using either direct or alternating current, the magnetic fields surrounding the electrodes cause a "fanning-out" or spreading of the welding arc in the plane of the electrodes. By positioning the electrodes so that their plane is transverse to the direction of welding travel, a wide, thin weld deposit results.

(The authors claim, though it is not described or illustrated, that "more than two welding electrodes can be introduced into this series system arranged to form an interlocking pattern of diverging weld zones to produce wider beads than obtained by a single pair of electrodes".)

Each electrode is fed into the welding zone independently by its own motor and voltage control system. Voltage control leads are connected between each welding head and the base-metal workpiece so that this potential is utilized to regulate each electrode feed independently of the other. The electrodes are adjusted to make contact with each other to form the welding arc within the pile of granular welding composition or "melt". When direct current is used for welding, it has been found that slightly deeper weld penetration occurs under the positive electrode.

(Continued on p. 142)

THE WISDOM OF EXPERIENCE

assures the highest purity and efficiency in

NIALK* *TRICHLORethylene*

for metal-cleaning and degreasing.

NIAGARA ALKALI COMPANY

60 East 42nd Street, New York 17, N. Y.

Liquid Chlorine • Caustic Potash • Carbonate of Potash • Paradichlorobenzene • Caustic Soda
TRICHLORethylene • NIAGATHAL* (Tetrachloro Phthalic Anhydride)
*Trade-mark

Tempilstiks®

The amazing Crayons that tell temperatures

A simple method of controlling temperatures in:

- WELDING
- FLAME-CUTTING
- TEMPERING
- FORGING
- CASTING
- MOLDING
- DRAWING
- STRAIGHTENING
- HEAT-TREATING IN GENERAL

Also available in pellet and liquid form

It's this simple: Select the Tempilstik® for the working temperature you want. Mark your workpiece with it. When the Tempilstik® mark melts, the specified temperature has been reached.

$2 gives up to 2000 readings

Available in these temperatures (°F)

113	263	400	930	1500
125	275	450	1000	1550
138	288	500	1050	1600
150	300	550	1100	1650
163	313	600	1150	1700
175	325	650	1200	1750
188	338	700	1250	1800
200	350	750	1300	1850
213	363	800	1350	1900
225	375	850	1400	1950
250	388	900	1450	2000

FREE —Tempil® *"Basic Guide to Ferrous Metallurgy"* — 16¼" by 21" plastic-laminated wall chart in color. Send for sample pellets, stating temperature of interest to you.

GORDON SERVICE

CLAUD S. GORDON CO.

Manufacturers & Distributors

Thermocouple Supplies • Industrial Furnaces & Ovens
Pyrometers & Controls • Metallurgical Testing Machines

Dept. 15 • 3000 South Wallace St., Chicago 16, Ill.
Dept. 15 • 2035 Hamilton Ave., Cleveland 14, Ohio

Series-Arc Welding

(Continued from p. 140)

For low-weld penetration and minimum base-metal dilution, a relatively low voltage between electrode and base metal is desirable. The most acceptable voltage lies between 20 and 25 volts. Above 30 volts, erratic and unstable operation is obtained. For cladding operations, where minimum penetration and dilution are desirable, a current of 350 to 450 amp. may be used with $\frac{5}{32}$-in. electrodes, with the electrodes contacting at ¼ to ⅜ in. above the base-metal surface. Travel speed may vary between 10 and 15 in. per min. The authors report that an angle of about 45° between the electrodes appears to be suitable.

Copper electrodes can be used with higher current and with electrode contact closer to the base metal than can mild steel electrodes. This is due to the higher electrical and thermal conductivity of copper.

Data on cladding $\frac{5}{32}$-in. steel of 0.24% carbon with 18-8, 25-12 and 25-20 stainless steels show a slight loss of chromium ascribed to oxidation by the fused "melt" and dilution by the base metal. Dilution also causes a slight drop in the nickel content but without apparent deleterious effect on the corrosion resistance.

The series-arc welding method for hard-facing applications produces a weld deposit of essentially the same composition as the electrode used. The high carbon retention is noticeable. "Sheathed" hard-facing electrodes have been used as successfully as "solid" electrodes, and it is now considered feasible to deposit many of the high-alloy metals heretofore deemed impractical because of base-metal dilution encountered with conventional submerged-arc welding methods.

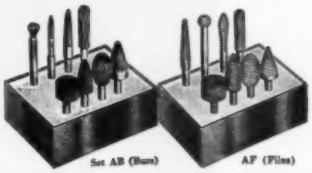
Data on cladding mild steel, with ¼-in. copper alloy electrodes using about 325 to 450 amp. d.c. at about 12 in. per min. travel speed, show a dilution of about 2½% for pure copper, 4% for silicon bronze and 6½% for aluminum bronze. With nickel and monel electrodes, travel speed was slower to avoid porosity and dilution was about 9 and 11% respectively. With the series-arc technique, metal can be deposited at a rate slightly greater than twice the rate of deposition obtained with the single-electrode method.

W. L. WARNER

MARTINDALE

ROTARY BURS AND FILES

Made of high-speed steel. Produced in our own factory where uniform hardness is assured by heat-treating in electric furnaces on which the temperature is closely controlled by electric eyes.



Sets AB & AF	Per Set
1 set	$11.05 net
2 to 11 sets	9.75 net
12 or more	8.45 net

The above sets, with ¼" diameter shanks, are composed of the 8 most popular sizes for general use.

Over 200 sizes and shapes (total over 75,000 pieces) are carried in stock for immediate shipment.

METAL-WORKING SAWS

Made of 18-4-1 High Speed Steel in 4 types for ferrous and nonferrous metals. Diameters range from 1¾" to 4".

"MOTOR-FLEX" GRINDERS

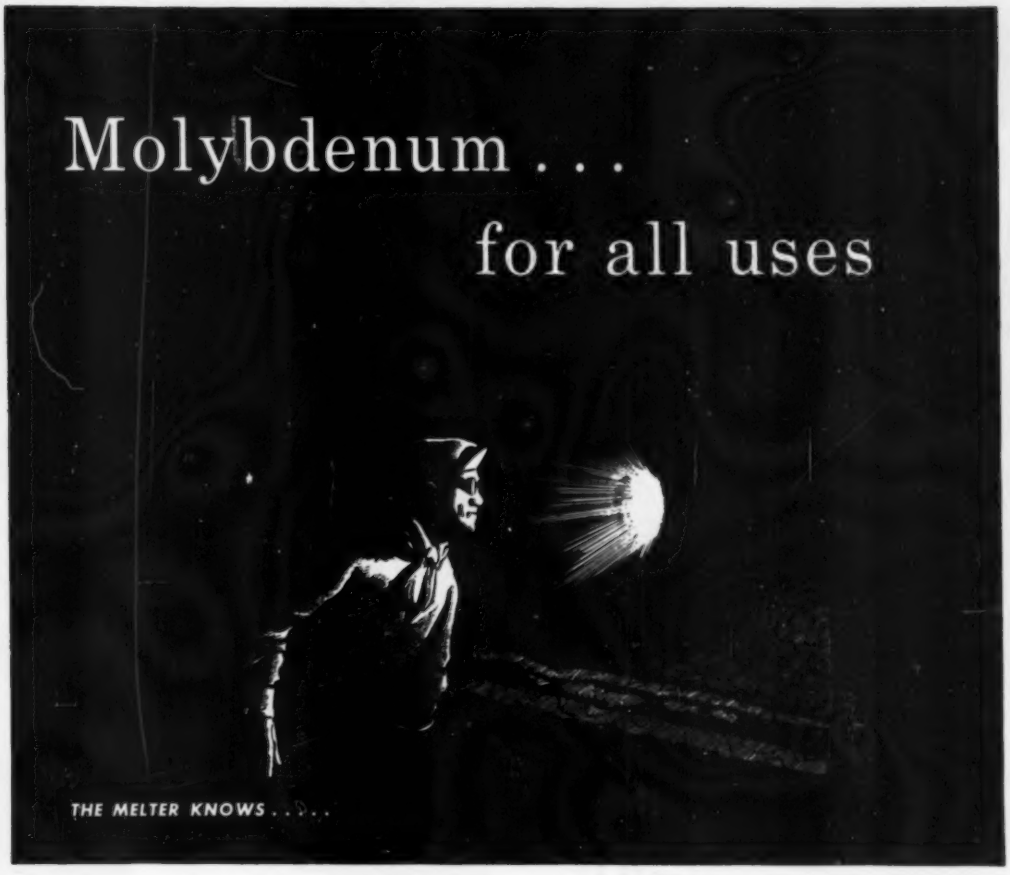
These high-quality, portable flexible-shaft tools are made in 7 types for operation on bench, floor, or overhead.

Write for 64-page Catalog No. 28 covering above and many other products for maintenance, safety, and production.

MARTINDALE ELECTRIC CO.

1372 Hird Avenue, Cleveland 7, Ohio

Molybdenum . . . for all uses



THE experienced melter knows he can depend on Molybdenum additions for uniform effects as calculated. He knows the customer can depend on the higher physical properties that Molybdenum adds. His comfortable assurance in the use of so trustworthy an agent is good to have. As a supplier of Molybdenum, Tungsten, and Boron, the Molybdenum Corporation is glad to be consulted at any time.

AMERICAN Production, American Distribution, American Control, Completely Integrated.

Offices: Pittsburgh, New York, Chicago, Cleveland, Detroit, Los Angeles, San Francisco, Seattle.

Sales Representatives: Edgar L. Fink, Detroit; Brumley-Donaldson Co., Los Angeles, San Francisco, Seattle.

Subsidiaries: Cleveland-Tungsten, Inc., Cleveland, O.; General Tungsten Manufacturing Co., Inc., Union City, N. J.

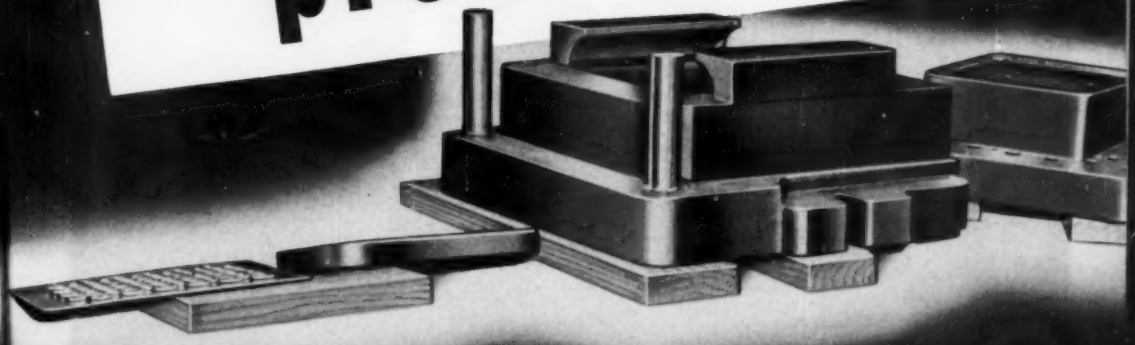
Works: Washington, Pa.; York, Pa.

Mines: Questa, New Mexico; Urad, Colorado.

MOLYBDENUM CORPORATION OF AMERICA
GRANT BUILDING PITTSBURGH, PA.

MCA

500% more production



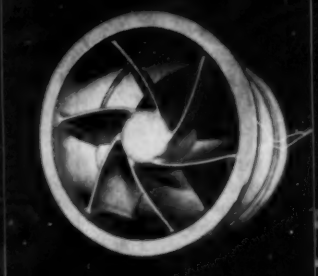
STEWART-WARNER CO.
Indianapolis, Indiana

MATERIAL DRAWN	Grade of Inconel used — Type AN-QQ-N-271, 16 gage Condition A, Commercial Sott. Type press — No. 8 Consolidated with air cushion. Speed of press — 25 strokes per minute.
ORIGINAL DIE	Original construction of die — Sectional punch of high carbon, high chrome, tool steel, hardened and ground. Form blocks for wiping up the sides were inserts of high carbon, high chrome, hardened and ground, with draw radii polished. These were mounted in cast iron retaining block.
ORIGINAL PRODUCTION	Location of parts — parts are located on pins mounted in air operated pressure pads. Results of operation prior to change—due to inconsistency in application of drawing compound, metal pickup on the draw radii caused the corner holes to become elongated and form oversize. Inserts had to be replaced after 2,000 pieces due to wear. The die required polish on the draw radii every 30 to 100 parts formed.
NEW AMPCO DIE	Change to Ampco — A grade 24 Ampco solid casting, 2 inches thick was inserted in the same cast iron retaining block and machined to form dimensions. Draw radii were polished.

RESULTS OF CHANGE — Greatly increased production — "Over 10,000 parts have been formed over this insert. No polishing of the draw radii has been required and the insert shows little indication of wear."

IT'S PRODUCTION-WISE TO AMPCO-IZE!

Gear blank — Centrifugally-cast of Ampco Metal. Note contours on ID.



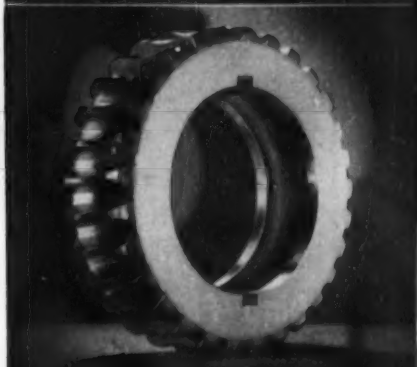
Pump diffuser — Cast of Ampco Metal.

Meter housings and fluid ends — Sand-cast of Ampco Metal.

---with AMPCO* METAL

The savings effected by the greatly increased production reported on the opposite page are typical of results obtained when long-wearing Ampco Metal is correctly applied. Wear-resistance, compressive strength, high impact and fatigue values, excellent bearing qualities, corrosion resistance — all these are cost-saving properties that make Ampco aluminum bronze alloys ideal for longer life and reduced downtime in many applications. Only a few can be shown here. Consult your nearest Ampco field engineer, or write for complete details.

*Reg. U. S. Pat. Off., Ampco Metal, Inc.



Gears — Centrifugally-cast Ampco Metal

Bushings — Centrifugally-cast Ampco Grade 18 standard bars.

Tear out this coupon and mail today!

Ampco Metal, Inc.
Milwaukee 46, Wisconsin
West Coast Plant
Burbank, California

AMPCO METAL, INC., Dept. MP-7, Milwaukee 46, Wisconsin

Send me your free Ampco Metal literature giving descriptions and general applications of Ampco Metal.

Name..... Title.....

Company.....

Company Address.....

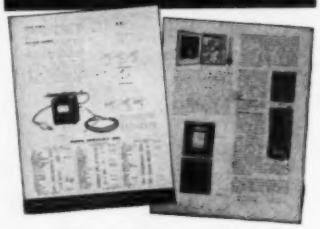
City..... (.....) State.....

9-7

Want to know more about GAS ANALYSIS?

Read this New 8-page ENGELHARD BULLETIN

Look at these Data-Packed Pages



YOU WILL FIND a wealth of material on a wide range of gas analysis problems and their solutions in the new Engelhard 8-page illustrated bulletin. It explains how Engelhard equipment provides complete, sensitive, accurate analyses by the proven thermal conductivity method. The bulletin also contains a *valuable thermal conductivity table* that you will want to keep for handy reference. *Write for your free copy today. Ask for Bulletin 800A.*

Please send me FREE copy of Bulletin 800-A on Gas Analysis.

Name .....

Company .....

Address .....

City ..... State.....X1234

CHARLES ENGELHARD, INC.
850 PASSAIC AVENUE, EAST NEWARK, N. J.

Photoplasticity Studies of Pressure Working*

STEPANOV, in 1949, showed the possibility of studying the process of plastic deformation in polycrystalline silver chloride by the use of polarized light. Since metals deform in a similar manner, information was thus obtained on their deformation characteristics.

The authors observed experimentally that organic substances of various structures also remain optically active during plastic deformation. Depending on the structure and composition, the optical activities of organic substances exhibited sharply different behaviors during plastic deformation. For example, several substances showed exceptional relaxation; the smallest change of loading produced rapid change of stress state. In these substances it was not possible to observe residual stress after unloading, regardless of the amount of plastic deformation. Other substances, on the contrary, after loading appeared to "freeze" at that stress condition which occurred during their plastic flow. Relief of stress, after unloading, occurred relatively slowly, and appreciable residual stress finally remained. Thus, it is possible by photoplasticity to study the stress condition in substances during plastic deformation. This fact is understandable, since plastic deformation is always accompanied by elastic deformation.

An organic substance was used to apply photoplasticity to the study of metal-working processes. This substance was characterized by great elasticity, and ordinary methods of preparation gave only large elastic deformation with retention of optical activity. However, at 30 to 40% elastic deformation, the optical activity was lost. A different preparation permitted this substance to change its form plastically, even at a small velocity of deformation.

Significant strengthening of the substance occurred during plastic flow. After unloading, the stresses produced during plastic deformation partially relieved themselves and some dimensional changes occurred. The final stresses and dimensions permitted the study of plastic deformation. The processes of upsetting and extrusion were chosen for study.

A. G. GUY

*Abstract of "Application of Photoplasticity to Modeling the Processes of Working Metals by Pressure", by S. J. Gubkin and S. I. Dobrovol'skii, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 91-93.

WANTED

General Superintendent for Ferro-Alloy Plant

Must be thoroughly experienced, particularly in the production of ferro-silicon and ferro-chrome. Excellent opportunity for a good reliable man. Please give complete record of experience and qualifications.

Answer to

Norris B. McFarlane
Assistant to the President

PITTSBURGH METALLURGICAL CO., INC.

Box 636. Confidential
NIAGARA FALLS, NEW YORK

Put **HEIL** Corrosion-Proof Equipment to work for YOU . . .

Sheet Neoprene Rubber-Lined Pickling Tank

• *LONGER LIFE* assured in your lined process equipment by our many years of experience in selecting and applying the best lining for your specific requirements.

- PLATING TANKS
- PICKLING TANKS
- CHEMICAL PROCESS
- RUBBER
- KOROSEAL
- LEAD

HEIL Process Equipment Corporation
12901 Elmwood Ave. • Cleveland 11, Ohio

Columbia TOOL STEEL

Deliveries—

Output is at an all-time high with our stocks now about 80% of "normal".

Deliveries of made-to-order material are averaging 90 to 120 days.

COLUMBIA TOOL STEEL COMPANY

ARTHUR J. CLEVELAND, PRESIDENT

500 EAST 34TH STREET • CHICAGO HEIGHTS, ILL.

LECOTHERM COMBUSTION BOATS

- Arrive in your laboratory carbon and sulfur blank free
- Packaged in anti-contamination capsules of ten boats each
- Unparalleled Slag Penetration Resistance
- Available in two styles

Send for Information

World's Largest Manufacturer of Combustion Boats

LABORATORY EQUIPMENT CORP.
Hilltop Road • St. Joseph 10, Michigan

Above: LECOTHERM Long Style Combustion Boats
Below: LECOTHERM Short Style Combustion Boats

Lecotherm Combustion Boat sectioned to show remarkable slag penetration resistance. Used with a one gram sample of steel combusted in oxygen at 2600° F

Send literature for LECOTHERM Combustion Boats to:

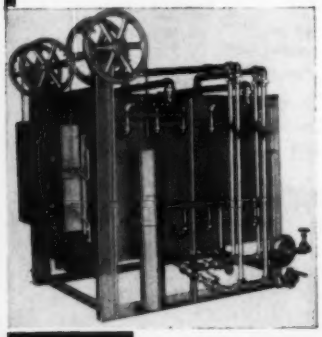
Name _____

Position _____

Company _____

City _____ State _____

BLOWPIPES TO FURNACES
A FULL LINE MADE
by the PIONEERS



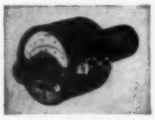
The AGF "SUPER" BLOW PIPE No. 1 is of a full line of varied sizes.

The AGF No. 225C Oven Furnace is one of a full line of large and small furnaces to suit any industrial need.

Write for Bulletin No. 200

AMERICAN GAS FURNACE CO
1002 LAFAYETTE STREET ELIZABETH 4, N. J.

WHY GUESS THE TEMPERATURE
. . . when you can see it!



THE NEW
PYRO RADIATION PYROMETER

Tells spot temperatures instantly in heat-treating furnaces, kilns, forgings and fire boxes. No thermocouples, lead wires or accessories needed! Temperature is indicated on direct-reading dial at a press of the button. Any operator can use it. In two double-ranges for all plant and laboratory needs.

Just sight it . . . and press the button!

Model No. 1: 1000-1800° F. and 1800-2600° F.
Model No. 2: 1400-2400° F. and 2400-3400° F.

Write for FREE Catalog No. 100.

PYRO OPTICAL PYROMETER

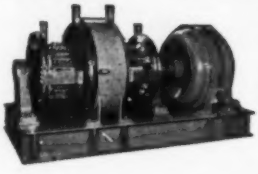
Accurate temperatures at a glance!

Any operator can quickly determine temperatures on minute spots, fast-moving objects and smallest streams. Completely self-contained. No calibration charts or accessories needed. An accurate, direct-reading Pyrometer that pays for itself by helping prevent spoilage. Weighs 3 lbs. Available in 5 temperature ranges (1400° F. to 7500° F.). *Write for FREE Catalog No. 80.*

THE PYROMETER INSTRUMENT COMPANY
New Plant and Laboratory
Bergenfield 8, N. J.

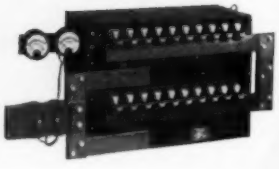
COLUMBIA

MOTOR GENERATORS



for
Electroplating
Anodizing
Electrocleaning
Electropolishing

- TANK RHEOSTATS
- REVERSING SWITCHES
- TONG TEST AMMETERS



Write for Descriptive Bulletins

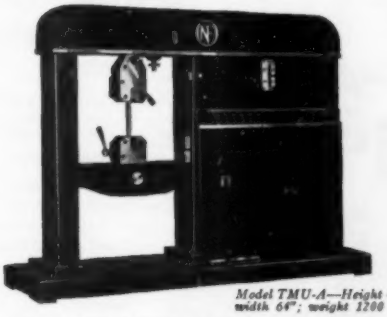
COLUMBIA ELECTRIC MFG. CO.
4531 Hamilton Ave. • Cleveland 14, Ohio

MERRILL
MATERIALS HANDLING DEVICES

MERRILL BROTHERS
56-31 ARNOLD AVE., MASPETH, N. Y.

It Will Pay to Make Your Own Tests with

NATIONAL FORGE
UNIVERSAL TESTING UNITS



Model TMU-A—Height 44"; width 64"; weight 1200 lbs.

The National Forge Universal Testing Machine, Model TMU, is compact, accurate, dependable, easy to operate and moderately-priced.

Wide working clearances, long stroke, quick-action simplified variable-speed control, improved grips and a wide spread of load scale ranges adapt this modern, streamlined unit to production, research or school instruction tests of a great variety of materials and specimen sizes. A.S.T.M. accuracy requirements are guaranteed.

Three load scale ranges: Model TMU-A—0-30,000, 0-6000, 0-600 lbs. Model TMU-B—0-15,000, 0-3000, 0-300 lbs.

Prompt deliveries of few units remaining in stock.

For details, write for Brochure 501.

TESTING MACHINE DIVISION

NATIONAL FORGE & ORDNANCE CO.

Dept. MP — IRVINE, WARREN COUNTY, PENNA.

CARL-MAYER HIGH TEMPERATURE FURNACE, recirculating air heater type, for temperatures up to 1200°F., as installed for Timken Roller Bearing Company. ● We also build Conveyor and Batch Type Furnaces up to 2000°F., for heat treating, normalizing, drawing, etc., using gas, oil and other fuels. ● Our many outstanding achievements make it well worth your while to consult Carl-Mayer Engineers on your next installation.

The CARL-MAYER Corp.

3030 Euclid Avenue, CLEVELAND, OHIO.

PYRASTEEL *Alloy* PARTS

for maximum resistance to

Write for PYRASTEEL Bulletin

PYRASTEEL Castings are the "main defense line" against destructive agents that impair ordinary steel parts.

PYRASTEEL is a modern-type, electric-furnace, chrome-nickel-silicon alloy that withstands oxidation and corrosion up to 2000° F., and also resists gases and most concentrated or dilute commercial acids.

Because of its proved durability under severe conditions, PYRASTEEL insures record serviceability and economy in such diverse applications as furnace parts, food processing equipment, chemical manufacturing, heat treating operations, and oil refinery work.

There is a suitable grade of PYRASTEEL for practically every purpose in heat-resistant applications.

CHICAGO STEEL FOUNDRY CO.

Kedzie Ave. & 37th St., Chicago 32, Ill. ● Makers of Alloy Steel for Over 40 Years

Perfect team for easy, inexpensive

Photomicrography
Photomacrography

Leitz

Aristophot
with
Ortholux

research
microscope

Lowest to highest magnifications. For plates and films 3¼ x 4¼ inches... 35mm. with the Leica Camera... black and white or color. Aristophot features include mirror reflex housing; time and instantaneous shutter; low power stage with focusing motion. The Ortholux gives you built-in illumination; large, square built-in mechanical stage; combined, inclined binocular observation and monocular photographic tube; mirror system, permitting use of vertical illuminators and Leitz Ultropak.

Write to Dept. Micro 104MP

E. LEITZ, Inc., 304 Hudson Street, New York 13, N. Y.
LEITZ MICROSCOPES • SCIENTIFIC INSTRUMENTS
BINOCULARS • LEICA CAMERAS AND ACCESSORIES

For Brazing at 2050° F.

Woven Wire Belts built by ASHWORTH are breaking records . . .

On three different installations
National Stamping Company, Detroit
Contract Specialties Corporation, Detroit
Salkover Metal Processing of Illinois, Chicago

Ashworth built Wire Belts have broken all previous records for this type of service, running up *to 7,000 and 8,000 hours at 2050°F.*

WHAT IS YOUR HANDLING or PROCESSING PROBLEM?

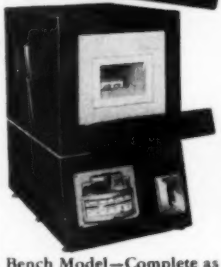
WRITE FOR ILLUSTRATED CATALOG 47P

ASHWORTH BROS., INC.
METAL PRODUCTS DIV. • WORCESTER, MASS.

Sales Engineers located in Buffalo • Chattanooga • Chicago • Cleveland • Detroit Los Angeles • New York • Philadelphia • Pittsburgh • Seattle
Canadian Rep., PECKOVER'S LTD. - Toronto - Montreal - Halifax - Winnipeg - Vancouver

---

High Temperatures for Small Quantities
HUPPERT "Hi-Temp" FURNACE



Bench Model—Complete as illustrated, $370.00. Floor Model—Matching stand with 2 compartments, $420.00.

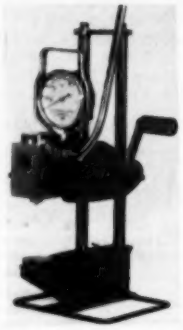
●This sturdy small furnace is designed for continuous operation up to 2200° F., or intermittent to 2250° F. Precision, low-cost operation makes it ideal for both laboratory and small run production. The "Hi-Temp" is equipped with automatic temperature control and has two pilot lights for indicating "ON" and "OFF" heating cycles. It employs Kanthal elements with fully enclosed contacts. Other noteworthy features are multi-insulation—all-steel construction and counterbalanced door. I.D. 5⅜" x 3⅜" x 6". O.D. 18" x 32" x 20½". Current consumption is 2 KW (110 V AC only).

Write for literature giving detailed description of this and other Huppert Ovens and Furnaces.

K. H. HUPPERT CO.
6844 COTTAGE GROVE AVENUE CHICAGO 37, ILLINOIS

KING PORTABLE BRINELL

HARDNESS TESTER



Eliminates excessive material handling costs in routine and special Brinell hardness testing. The King Portable Brinell can be carried to the work, used in any position, and always puts an actual load of 3000 kg. on the 10-mm. ball indenter.

This 27-lb. portable tester has a 4-in. deep throat and a gap 10 in. high. For larger pieces, the test head is easily removable for testing sections beyond the capacity of the standard base.

Throat—4" deep. Gap—10" high. Weight—26 lbs.

Simple to operate, the tester is impossible to overload, and even with inexperienced operators will provide consistent accurate results well within the requirements of the Bureau of Standards.

ANDREW KING

NARBERTH, PENNA.

BUZZER *Gas* BURNERS

For Many Industrial Gas Uses

NO BLOWER or POWER NECESSARY
. . . just connect to gas supply

Designed to solve numerous Industrial Gas applications, "BUZZER" Burners are unexcelled for Efficiency, Economy, Simplicity and Flexibility. Large variety of models available.

Send for the "BUZZER" Catalog showing complete line of Industrial Gas Burners, Furnaces and other equipment.

CHARLES A. HONES, INC.

123 So. Grand Ave. Baldwin, L. I., N. Y.

How one Pittsburgh Brush*

POLISHES 10,000 HEATING UNITS

** An actual case history from The Edwin L. Wiegand Company, producers of CHROMALOX Heating Units.*

WHEN this company needed a way to take the ragged edges off heating units economically and *fast*, they turned to sturdy, tough Pittsburgh Brushes for the answer. The 6" Pittsburgh steel wire brushes like that shown above polish 10,000 heating units during their life.

LET PITTSBURGH ENGINEERS SOLVE YOUR BRUSH PROBLEMS

Pittsburgh's complete line of brushes of every type, for every purpose, will provide a practical, economical solution of any brush problem you might have. Drop us a line on your company letterhead for a copy of our new booklet that shows, through actual case histories, how Pittsburgh can help cut your brushing operation costs. Address: PITTSBURGH PLATE GLASS COMPANY, *Brush Div.*, Dept. W7. 3221 Frederick Ave., Baltimore 29, Md.

PITTSBURGH

PG *Power Driven* **BRUSHES**

BRUSHES • PAINT • GLASS • PLASTICS

PITTSBURGH PLATE GLASS COMPANY

Metal Progress

Taylor Lyman, *Publisher*

A. P. Ford, *Sales Manager*

George H. Loughner, *Production Manager*
7301 Euclid Ave., Cleveland 3—UTah 1-0200

Harry L. Gebauer and John F. Tyrrell, *Eastern Managers*
55 W. 42nd St., New York 18—CHickering 4-2713

Ralph H. Cronwell, *Western Manager*
482 Burton Ave., Highland Park, Ill.—Highland Park 2-4263

Don Harway, *Pacific Coast*
1709 West 8th St., Los Angeles 14—DUnkirk 2-8576

PUBLISHED BY AMERICAN SOCIETY FOR METALS, 7301 EUCLID AVE., CLEVELAND 3, OHIO—W. H. EISENMAN, SECRETARY

Index to Advertisers

Acheson Colloids Corp. ... 109
Air Reduction Sales Co. ... 24-25
Ajax Electric Co. ... 5
Ajax Electrothermic Corp. ... 10
Ajax Engineering Co. ... 113
Allied Research Products, Inc. ... 116
Alloy Engineering & Casting Co. ... 4
Alloy Rods Co. ... 129
Aluminum Co. of America ... 16A, B, C, D, E
American Brass Co. ... 112
American Chemical Paint Co. ... 122
American Cyanamid Co. ... 18
American Gas Furnace Co. ... 148
American Optical Co. ... 6
American Smelting & Refining Co. ... 23
American Society for Metals ... 123
Ames Precision Machine Works ... 102
Ampco Metal, Inc. ... 144-148
Ashworth Brothers, Inc. ... 130

Barrett Div.,
Allied Chemical & Dye Corp. ... 135
Bausch & Lomb Optical Co. ... 88D
Bell & Gossett Co. ... 26
Bethlehem Steel Co. ... 44, 107
Brandt, Inc., Chas. T. ... 27
Buehler, Ltd. ... 26

Carborundum Co. ... 34
Carl-Mayer Corp. ... 149
Carlson, Inc., G. O. ... 108
Carpenter Steel Co. ... 42
Chase Brass & Copper Co. ... 14
Chicago Steel Foundry Co. ... 149
Christiansen Corp. ... 19
Cities Service Oil Co. ... 103
Clark Instrument, Inc. ... 32
Climax Molybdenum Co. ... 138
Cold Metal Products Co. ... 32B
Columbia Electric Mfg. Co. ... 148
Columbia Tool Steel Co. ... 147
Copperweld Steel Co. ... Back Cover

Delaware Tool Steel Corp. ... 30
Despatch Oven Co. ... 7
Distillation Products, Inc. ... 22
Dow Chemical Co. ... 2
Driver-Harris Co. ... 43

Eastman Kodak Co. ... 101
Eberbach Corp. ... 128
Electric Furnace Co. ... Inside Back Cover
Electro Alloys Co. ... 1
Electro Metallurgical Div.,
Union Carbide & Carbon Corp. ... 97
Engelhard, Inc., Chas. ... 146
Enthone, Inc. ... 11

Fisher Scientific Co. ... 139

General Alloys Co. ... 137
Gordon Co., Claud S. ... 138, 142
Great Lakes Steel Corp. ... 41
Gulf Oil Corp. ... 17

Harper Electric Furnace Corp. ... 140
Haynes Stellite Co.,
Union Carbide & Carbon Corp. ... 119
Heil Process Equipment Corp. ... 147
Hevi Duty Electric Co. ... 130
Holcroft & Co. ... 114
Hones, Inc., Chas. A. ... 131
Hoskins Mfg. Co. ... 45
Huppert Co., K. H. ... 150

Inland Steel Co. ... 50
International Nickel Co., Inc. ... 46, 80A
Ipsen Industries, Inc. ... 32A

Jarrell-Ash Co. ... 124
Jessop Steel Co. ... 128A
Johns-Manville ... 133

Kemp Mfg. Co., C. M. ... 110
King, Andrew ... 131

Laboratory Equipment Corp. ... 147
Lakeside Steel Improvement Co. ... 140
Lavin Sons, Inc., R. ... 40
Leeds & Northrup Co. ... 3
Leitz, Inc., E. ... 150
Lester-Phoenix, Inc. ... 125B
Lindberg Engineering Co. ... 21
Linde Air Products Co.,
Unit of Union Carbide & Carbon Corp. ... 36
Loftus Engineering Corp. ... 115

McKay Co. ... 13
Marley Co., Inc. ... 16F
Martindale Electric Co. ... 142
Merrill Brothers ... 148
Michigan Steel Casting Co. ... 131

Milne & Co., A. ... 100
Minneapolis-Honeywell Regulator Co.
(Industrial Div.) ... 16
Molybdenum Corp. of America ... 143

National Carbon Div.,
Union Carbide & Carbon Corp. ... 33
National Forge & Ordnance Co. ... 149
National Machinery Co. ... 8
National Radiator Co. ... 134
Niagara Alkali Co. ... 141
Norton Co. ... 48

Ohio Crankshaft Co. ... 37
Ohio Nut & Bolt Co. ... 31
Ohio Steel Foundry Co. ... 128
Olsen Testing Machine Co., Tinius ... 38

Park Chemical Co. ... 47
Peterson Steels, Inc. ... 128
Picker X-Ray Corp. ... 111
Pittsburgh Metallurgical Co., Inc. ... 146, 152
Pittsburgh Plate Glass Co. ... 151
Pressed Steel Co. ... 103
Pyrometer Instrument Co. ... 148

Radio Corp. of America ... 135
Republic Steel Corp. ... 12
Revere Copper & Brass, Inc. ... 99
Reynolds Metals Co. ... 112A & B
Rolock, Inc. ... 39

Sharon Steel Corp. ... 80C
Stuart Oil Co., D. A. ... 104
Sunbeam Stewart Industrial Furnace Div. ... 117
Surface Combustion Corp. ... Inside Front Cover

Timken Roller Bearing Co. ... 35
Titanium Alloy Mfg. Div.,
National Lead Co. ... 123

Union Carbide & Carbon Corp. ... 33, 36, 97, 119
United States Pipe & Foundry Co. ... 120-121
United States Steel Co. ... 126-127

Vanadium Corp. of America ... 28

Westinghouse Electric Corp. ... 118
Wheelock, Lovejoy & Co., Inc. ... 132
Wilson Mechanical Instrument Co. ... 106
Wisconsin Steel Co. ... 9

Youngstown Sheet & Tube Co. ... 15

WANTED

ONE (1)
FURNACE
TRANSFORMER

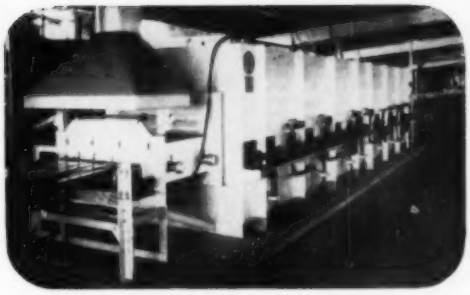
Capacity—any size from 7500 KVA to 10,000 KVA. Three Phase, 60 cycles, oil insulated, water cooled, 13,200 volts primary, with primary over-wound to give a secondary range of voltage of 100 to 170 volts in steps controlled by externally operated no load tap changer. High voltage bushings in oil filled compartment with 15 KV potheads. Low voltage terminals to be in the form of copper bars emanating through the top of the transformer tank and to be interleaved.

Reply to: Mr. R. B. DeLisle, General Purchasing Agent

PITTSBURGH METALLURGICAL CO., INC. P. O. BOX 636, NIAGARA FALLS, N. Y.

TOWER PRESS, CLEVELAND

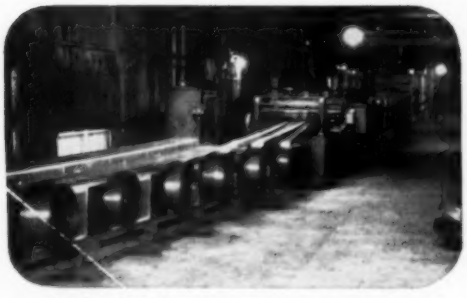
Steel strip in single or multiple strands up to a total width of 54" may be bright annealed or normalized, continuously, in this EF gas fired radiant tube installation. Capacity 7200 lbs. per hour.



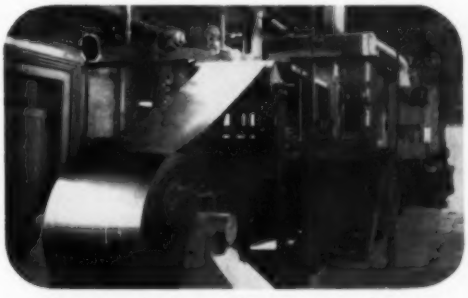
An EF electrically heated special atmosphere installation bright annealing six parallel strands of cold rolled steel strip, continuously. Handles single or multiple strands up to a total width of 30".

SOME TYPICAL EF INSTALLATIONS

For Processing Strip



Another EF gas fired radiant tube, continuous furnace for bright annealing or normalizing cold rolled strip steel. Has preheater or burn-off chamber and handles 2000 lbs. strip per hour.



An EF special atmosphere furnace with flame preheating burn-off or oxidizing section, and controlled heating and cooling zones for producing various surface conditions on strip steel.

Designed and Built by

The Electric Furnace Co., Salem, Ohio

Gas Fired, Oil Fired and Electric Furnaces — For Any Process, Product or Production

This EF combination fuel fired and electrically heated strip processing unit provides extreme flexibility in heating, soaking and controlled cooling cycles for treating various grades of strip.

Stainless steel strip is bright or process annealed continuously in this EF gas fired special atmosphere tube muffle-type furnace. It also handles other strip requiring lower temperatures.

ARISTOLOY STEELS

The Symbol of Quality...

IN ELECTRIC FURNACE STEELS

STANDARD STRUCTURAL ALLOY

BEARING QUALITY

ALLOY TOOL

SPECIALTY

NITRALLOY

CARBON TOOL

MAGNAFLUX-AIRCRAFT QUALITY

Hot Rolled • Forged • Annealed • Heat Treated
Normalized • Straightened • Cold Drawn
Machine Turned • Centerless Ground

COPPERWELD STEEL COMPANY

WARREN, OHIO

117 Liberty Street
New York, New York

1578 Union Commerce Bldg.
Cleveland, Ohio

528 Fisher Building
Detroit, Michigan

176 W. Adams Street
Chicago, Illinois

7251 General Motors Bldg.
Detroit, Michigan

3104 Smith Tower
Seattle, Washington

P.O. Box 1633
Tulsa, Oklahoma

403 W. Eighth Street
Los Angeles 14, Calif.

Monadnock Building
San Francisco 5, Calif.

4004 Navigation Blvd.
Houston 3, Texas

IT'S BETTER TO USE THE BEST!